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An investigation of destroyer midship section design with varying longitudinal and web frame spacing

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AN INVESTIGATION OF DESTROYER MIDSHIP SECTION DESIGN WITH VARYING LONGITUDINAL AND WEB FRAME SPACING

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SUBMITTED IN PARTIAL FULFILLMENT OF THE
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ABSTRACT

AN INVESTIGATION OF DESTROYER MIDSHIP SECTION
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by

Robert Oliver Dulin, Jr.

Submitted to the Department of Naval Architecture and Marine Engineering on May 19, 1967, in partial fulfillment of the requirements for the Master of Science degree in Naval Architecture and Marine Engineering and the Professional degree, Naval Engineer.

The attractive possibility of minimizing ordering, handling, and warehousing problems by employing uniform longitudinal scantlings and constant plating thicknesses throughout the midship section led to the decision to carry out an investigation of such a design methodology. The design technique proved to be feasible, but less economical than conventional techniques of midship section design.

A computer tool for the systematic variation of longitudinal intervals has been developed and is now ready to be applied to midship section design with varying structural materials and different plating thicknesses and longitudinal scantlings.

Thesis Supervisor: J. Harvey Evans

Title: Professor of Naval Architecture

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I. INTRODUCTION

"The quest for least weight, lowest cost, optimal ship structures has long been hampered by the lack of reliable quantitative data in adequate amount. And the problem has, so far, proven only partially susceptible to closed form solution. In no real sense, therefore, has it been possible to weigh the relative merits of new materials of construction, for example, or variations of frame spacing, different combinations of framing systems or alterations of principal dimensions (should they too be of interest)." [6] (Emphasis added)

The midship section design of longitudinally framed warships has long been carried out on the basis of a constant spacing of the longitudinal structural stiffeners, with varying stresses and loadings being accounted for by the variation of plating thicknesses and longitudinal scantlings.

This conventional procedure has resulted in the development of designs of adequate strength, but the goal of the optimum least weight, lowest cost ship structural design has proved to be an elusive one.

Current design techniques, although effective, add to the cost of ship construction by the price penalties involved in the procurement of a diversity of plates and shapes.

Similarly, parts handling and inventory control is complicated and rendered more difficult and expensive. These problems and deficiencies resulting from conventional midship section design procedures suggested the novel approach which is the subject of this investigation.

Fundamentally, in an evaluation of an extreme variation from current procedures, this modified design methodology generates a design with a uniform plating thickness throughout, with a uniform longitudinal scantling (exclusive of the keel) similarly selected. Variations in loading are compensated for by different intervals between longitudinals throughout the midship section.

In order to permit a reasonable inference as to the relative merits of this modified design methodology, the FORREST SHERMAN (DD-931) class destroyer midship section has been taken as a model for comparative purposes.

II. PROCEDURE

For purposes of consistency with the techniques used in the original design of the FORREST SHERMAN, the design procedured elucidated in [1], have been used throughout this investigation, modified as necessary. The same basic stress criteria have been used, with the maximum primary compressive stresses on DD-931 specified as design limiting values. As for the FORREST SHERMAN, high tensile steel (HTS) has been used throughout the midship section.

The calculations required for this investigation have been carried out almost exclusively by a series of computer programs and subroutines, explained in detail in the Appendix.

Input data, including the plating molded offsets, are generated for eventual use in the main design program, RUNSCORE, and the main costing program, COSTDATA. Existing plates and scantlings were used throughout the investigation in order to permit a realistic evaluation of costs and structural characteristics. Actual costing criteria in use at the Boston Naval Shipyard were employed in conjunction with current Federal parts costing information.

Once the input information has been determined, the detailed design process is carried out. First, given the transverse frame spacing and the minimum tolerable longitudinal

spacing, the least possible plating thickness is calculated, and the resultant permissible longitudinal separation computed.

This permissible separation is applied at the keel, thereby locating the longitudinal adjacent to the keel. The permissible span to the next longitudinal and the required longitudinal are then determined. This computation is repeated until the deck-shell intersection is reached. At this time, the spacings are reduced if necessary to assure the existence of at least the minimum permissible spacing between the last shell longitudinal and the deck edge.

The deck longitudinals are located in a like manner. The arrangement is required to be symmetrical about the centerline, with either a longitudinal at the centerline or the centerline exactly at mid-span between longitudinals. If necessary, the interval between the deck longitudinals is reduced.

After all the midship section longitudinals have been located, the required scantlings at each location are calculated. The heaviest of these is then selected for use throughout the midship section.

With the plating thickness selected, longitudinals located and scantlings determined, the overall midship section characteristics are calculated. The maximum primary compressive stresses at the keel and deck centerline are determined, using the hull girder bending moments that

were calculated for the FORREST SHERMAN.

Should either of the calculated stresses exceed the comparable values actually existing on the DD-931 as built, the plating thickness is increased and the entire cycle is repeated with larger longitudinal spacings inevitably resulting. If the stresses are acceptable, the calculation is terminated.

The costing procedure evaluates the expense, per foot length, of building the midship section. Most of the charges are based on an arbitrary cost of $7.50 per man-hour (M-H) of work. This charge includes shipyard overhead expenses. Government price data is used to determine the acquisition costs for structural materials.

The weight and cost of the modified design is then compared with similarly-calculated values for the DD-931 as built.

III. RESULTS

Two basic series of midship section design calculations were carried out by main program RUNSCORE. The first of these computed designs with the minimum acceptable interval between longitudinals fixed at 1.667 feet, while the transverse frame spacing varied from 6 to 8 to 10 feet. The second series calculated designs for a transverse frame spacing fixed at 8 feet with the interval between longitudinals stipulated to be a minimum of either 1.667, 2.000, or 2.333 feet.

Not surprisingly, the midship section designs developed with constant plating thicknesses and uniform longitudinal scantlings proved to be consistently heavier and, for less apparent reasons, which are discussed in the following section, more expensive to build.

The results of the calculations for different transverse frame intervals are presented in Table I, as well as similar data for the FORREST SHERMAN as built. Figure I shows a schematic plan of the DD-931 midship section as built, while Figure II shows a schematic for the midship section design resulting from a transverse frame spacing of 8 feet with a minimum specified longitudinal interval of 1.667 feet. Note the heavy plating, heavy longitudinals, and great in-

tervals between longitudinals in the new midship section design. Table I also provides detailed cost data for the three new designs as well as the original DD-931, using identical reference data for all four cases.

Detailed information as to the location of longitudinals and the intervals between longitudinals is provided in Table II, which delineates the designs developed by the first series of computations.

The second series of computer runs revealed this design methodology to be very insensitive to the specification of minimum tolerable intervals between longitudinals, with the exception of the minor effects caused by possible adjustments for the deck-shell intersection of the deck centerline criteria for longitudinal intervals. As a consequence, the designs for all intents and purposes were identical regardless of the specified minimum intervals between longitudinals.

TABLE I

MIDSHIP SECTION DESIGNS
WEIGHT AND COST SUMMARIES

DESIGN:	New Study	New Study	New Study	DD-931 (As Built)
FRM (Ft.)	6.00	8.00	10.00	8.00
THL (In.)	0.75	0.75	0.75	(Varies)
WEIGHTS (Pounds per foot hull length)				
TOTAL:	4736.6	4716.7	4748.0	3591.0
Plating	3854.0	3854.0	3854.0	2724.5
Longitnls.	505.3	505.3	548.5	509.1
Tr. Framing	377.2	357.4	345.5	357.4
COSTS (Per foot hull length)				
TOTAL:	$ 1568.01	$ 1471.78	$ 1417.65	$ 1344.41
Plating	464.97	466.61	464.97	336.98
Longitnls.	66.30	66.30	70.20	70.50
Keel	27.56	27.56	27.56	27.56
Tr. Framing	404.96	303.72	242.98	303.72
Pl. Welding	298.64	301.33	298.64	256.67
Pl. Cutting	2.02	2.70	2.02	0.00
Pl. Rolling	23.40	23.40	23.40	19.18
L. Welding	113.50	113.50	120.18	142.50
Fl. Cutting	17.85	17.85	18.90	28.50
Rigging	148.80	148.80	148.80	148.80

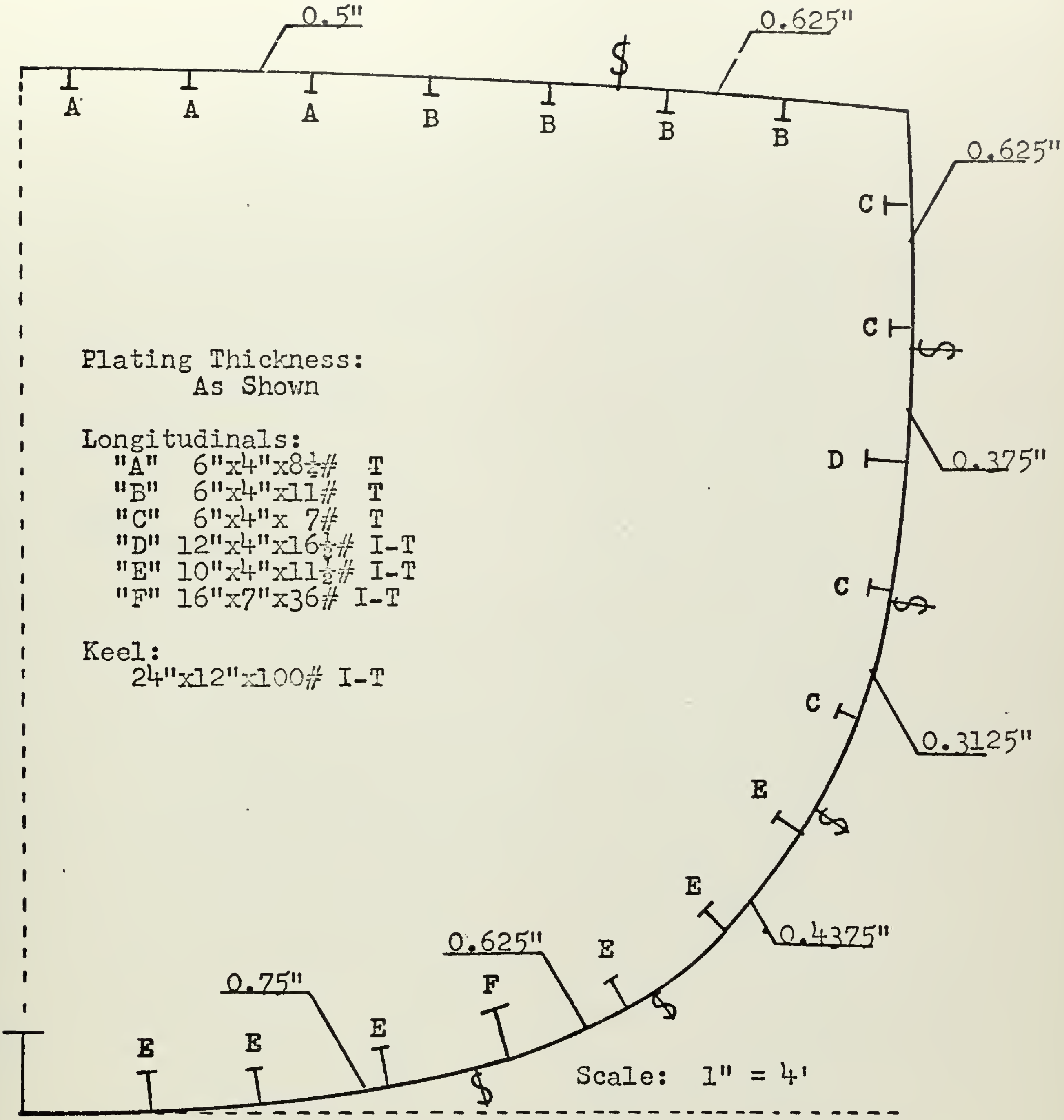


FIGURE I

THE ORIGINAL DD-931 MIDSHIP SECTION DESIGN [5]

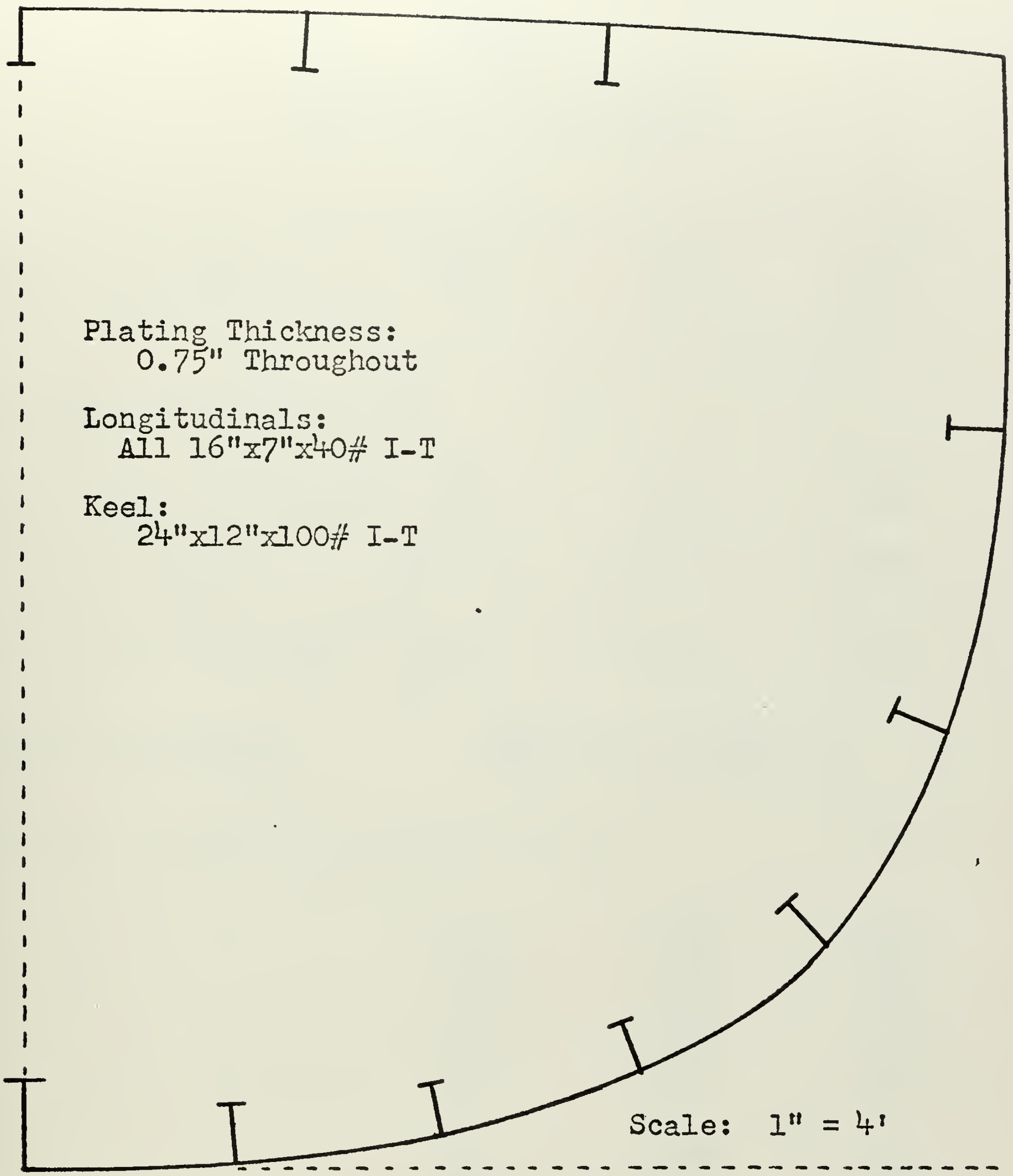


FIGURE II

MODIFIED DD-931 MIDSHIP SECTION DESIGN

TABLE II

MIDSHIP SECTION DESIGNS
STRUCTURAL DESCRIPTION

Frame Spacing (Ft.)	6.00	8.00	10.00
Plating Thickness (In.)	0.75	0.75	0.75
STRUCTURAL CHARACTERISTICS			
Keel Stress (Tons/In.^{2})	7.43	7.43	7.43
Deck Stress (Tons/In.^{2})	4.58	4.59	4.45
Moment of Inertia (In.^{2} Ft.^{2})	142,120	142,105	143,819
N. A. above Base Line (Ft.)	14.26	14.25	14.46
Keel Longitudinal	24" x 12" x 100# I-T		
Other Longitudinals	10" x 7" x 40# I-T		
INTERVALS BETWEEN LONGITUDINALS* (Feet)			
	4.717	4.717	4.717
	4.780	4.751	4.751
	4.888	4.852	4.852
	5.157	5.110	5.110
	5.837	5.724	5.724
	7.295	6.935	6.934
Deck-Shell Intersection	7.931	8.516	8.517
	9.831	9.079	8.687
	6.822	6.777	6.500
	5.717**	6.514**	6.350
			0.833***

*The first interval begins at the keel.
**A longitudinal lies on the deck centerline.
***The deck centerline lies midway between two longitudinals.

TABLE III

TYPICAL DESIGN SUMMARY*

PLATE THICKNESS Inches	TOTAL WEIGHT Pounds	KEEL STRESS $Tons/In.^2$	MOM. OF INERTIA $In.^2 Ft.^2$	LONGITUDINALS NO.	LONGITUDINALS SCANTLING
0.28125	2655.9	13.47	76,183	54	8x5.4x20
	Stresses are excessive, design repeated.				
0.3125	2709.5	13.38	77,391	48	10x5.8x21
	Stresses are excessive, design repeated.				
0.34375	2781.9	12.95	79,760	42	10x5.8x21
	Stresses are excessive, design repeated.				
0.375	2898.4	12.43	83,690	39	10x5.8x21
	Stresses are excessive, design repeated.				
0.4375	3131.4	11.45	91,387	33	10x5.8x21
	Stresses are excessive, design repeated.				
0.500	3393.8	10.52	100,012	29	10x5.8x21
	Stresses are excessive, design repeated.				
0.625	3918.8	9.03	117,352	23	12x 4 x16.5
	Stresses are excessive, design repeated.				
0.750	4716.7	7.43	142,105	17	16x 7 x40
	Design acceptable, calculations terminated.				

*Main program RUNSCORE computation for transverse frame spacing of 8.0 feet, specified minimum longitudinal interval of 1.667 feet.

IV. CONCLUSIONS AND RECOMMENDATIONS

The midship section design of a longitudinally-framed warship with uniform longitudinal scantlings and constant plating thicknesses has been shown to be feasible.

Table I on page 8 vividly shows that the major contributor to the poor relative performance of this design methodology in terms of both weight and cost was the shell plating. Much of the added material near the neutral axis and on the deck (relative to the DD-931 as built) was very inefficiently applied, as is evident in the low stress levels existing in the deck structure of the new designs. Similarly, the cost of welding and fabrication of the shell plating was materially increased by the presence of the heavier plating throughout the girth of the midship section.

There appears to be a distinct reduction in cost per unit length as the interval between transverse frames is increased. This is apparently the consequence of the application of the cost of this framing to the overall structural cost. The cost per foot length of the transverse framing varies markedly as the interval between the frames is increased. Similarly, the weight of the transverse framing per foot hull length reduces as the interval between the frames is increased, although to a much smaller degree than the

cost varies.

No distinct trends in total weight per unit length were apparent in this investigation. The major factor leading to variations in weight was the number of longitudinals required, as both the selected plating thickness and longitudinal scantling were identical for all three cases examined in detail.

Unfortunately, no information was available to permit a reasonable estimation of the savings to be realized by the volume acquisition of identical structural members. This economy, along with the reduced handling and storage costs, should be incorporated in any such analysis as this, but is very doubtful that these savings would be of such magnitude as to offset the disparities existing between the new designs and the costs of consturction of the original DD-931 midship section design.

The traditional design concept of varying plating thicknesses and longitudinal scantlings is a sound one. This approach promises to be even more valuable when incorporated with the techniques developed in this investigation for the variation of the intervals between longitudinals. Furthermore, the use of different structural materials should be investigated in detail. Very frequently stability criteria dictate the plating thicknesses required when using high strength steels such as HY-80. The variation of longitudinal intervals would permit the use of much thinner plates in heavily stressed areas without the problems of plate stability

otherwise to be encountered. Appreciable weight economies should be realized from the superposition of the technique of variation of longitudinal intervals with the use of different structural materials while varying plating thicknesses and longitudinal scantlings.

The design of a midship section with a single plating thickness throughout and uniform longitudinal scantlings proved to be workable but less efficient than conventional techniques. The basic idea of varying longitudinal intervals is sound, and detailed studies of variations on this basic idea should be carried out.

APPENDIX

PROGRAM DOCUMENTATION

The structural and cost calculations for the midship section design were generated by a series of computer programs and subroutines, listed below, which are described and explained in detail on the following pages. A program listing, flow chart, and sample calculation accompanies the description of the operation of each program or subroutine.

All programs and subroutines were written in FORTRAN IV and were run on the IBM 360/65 computer.

Main Programs:

A. RUNSCORE
B. COSTDATA

Subroutines called by Main Programs.

C. TSLECT
D. HDWTR
E. CSPACE
F. CLONGL
G. PMINER

Subordinate Programs used to generate input data for Main Programs:

H. SHDATA
I. DKDATA
J. PTLGTH
K. WTSMOD
L. TSHAPE
M. COSTKL

A. MAIN PROGRAM RUNSCORE

1. DESCRIPTION

Introduction

Main program RUNSCORE carries out the design calculation for the midship section of DD-931, selecting one plating thickness and one longitudinal scantling (except for the keel) to be used throughout the structure. The basic computational methods described by St. Denis [1] are used, modified as necessary.

This program is not designed to optimize the characteristics of the midship section. The required plating thickness is selected, the spans between the various longitudinals are determined, and the required longitudinal scantlings are evaluated. Once the structural design has been completed, the net section characteristics are evaluated and the resultant primary compressive stresses are compared with the design criteria. Should the design be overstressed, the next greater available plating thickness is selected, and the entire cycle is repeated. RUNSCORE uses existing HTS plating thicknesses and longitudinal scantlings, as opposed to any idealized materials with a continuous range of available sizes. This, inevitably,

results in overdesigned structures in many cases.

After the input phase has been completed, subroutine TSLECT determines the minimum permissible plating thickness, dictated by the minimum tolerable longitudinal spacing specified as an input to the program. This subroutine also determines the greatest permissible interval between longitudinals for the stresses and hydrostatic loadings existing at the keel.

Beginning at the keel, the program "climbs" the girth of the midship section. The first longitudinal is located using the maximum permissible interval determined by subroutine TSLECT. Subroutine CLONGL then calculates the required longitudinal scantling for this location, and subroutine CSPACE evaluates the span to the next longitudinal, and the cycle is repeated. When the shell-deck intersection is reached, the program is designed to assure that the span to the intersection is at least the minimum permissible value. The distance to the intersection is compared with this minimum and, if necessary, the span is increased by reducing the spacings between the preceding longitudinals in the shell structure. This longitudinal relocation algorithm is so structured as to prevent the inadvertent reduction of longitudinal spans to less than the minimum tolerable value. Once the location of all longitudinal-plating intersections on the shell has been satisfactorily completed, the program proceeds to the

similar location of the deck longitudinals.

The deck calculations are carried out in a manner identical to that used for the side shell. RUNSCORE is so structured that the midship section must be symmetrical, with a deck longitudinal on the centerline or the centerline exactly at mid-span between two deck longitudinals. As for the side shell, the spacings in all cases must be at least equal to the minimum permissible value. If necessary, provision is made for the systematic reduction of spans between longitudinals to insure that this is the case. Up to this point, the program has assumed that the longitudinals were of adequate strength, with no specific determination of scantlings.

With all longitudinal locations now determined, the required scantlings for each specific location are calculated, with the heaviest needed anywhere in the structure selected for use throughout the structure. Criteria as to the minimum radius of gyration, stiffener strength, stiffener critical strength, and the stability of the stiffener-plating combination must all be satisfied.

With the plating thickness and longitudinal scantlings determined, subroutine PMINER is called to provide the information needed to calculate the contribution of the plating to the moment of inertia and cross-sectional area of the overall midship section. The effects of the

longitudinals are combined with this to determine the total cross-sectional area and moment of inertia for the entire midship section.

The structural weight of the midship section is evaluated in some detail. The total weight per foot length, including an approximate valuation of the contribution of the transverse framing to the net weight, is calculated in pounds and tons. The contributions of the plating, longitudinals, and transverse framing are similarly determined, but only in terms of pounds per foot length.

With the overall section characteristics fixed, the actual hogging and sagging bending moments used in the design of the DD-931 are employed in the calculation of the actual primary compressive stresses exerted in the keel and deck structure. Should either of these exceed the design limiting values, the plating thickness is increased to the next greater value, and the entire computation is repeated. This iterative process is carried out until both primary compressive stresses are determined to be less than the maximum permissible values.

Inputs

Symbol	Meaning
PTDATA(I,J,1)	Half breadth to point (I,J). (Feet)
PTDATA(I,J,2)	Height of point above base line. (Feet)
PTDATA(I,J,3)	Distance to next point on girth. (Feet)

Symbol	Meaning
ST1CRK	Maximum permissible stress at keel. (Tons/In.^{2})
ST1CRD	Maximum permissible stress at deck centerline. (Tons/In.^{2})
ST2EST	Estimated value of secondary stress. (Tons/In.^{2})
SGMULT/SGMYLD	Yield stress of the plating. (Tons/In.^{2})
A3HEEL	Specified maximum heel angle. (= 0.5236 radians)
D1	Depth of hull. (= 26.231247 feet)
H1AMDK	Specified design head of water above main deck. (= 4.0 feet)
H1DFL	Design full load draft. (= 14.5 feet)
XLGTNL(I,1)	Maximum moment of inertia of stiffener (I). (In.^{4})
XLGTNL(I,2)	Stiffener minimum moment of inertia. (In.^{4})
XLGTNL(I,3)	Stiffener area. (In.^{2})
XLGTNL(I,4)	VCG of stiffener from the cut flange. (In.)
XLGTNL(I,5)	Stiffener overall depth. (In.)
W5BMIN	Minimum permissible longitudinal spacing. (Feet)
FRM	Transverse frame spacing. (Feet)

Calculated Items

Symbol	Meaning
XLONGL(I,1)	Half breadth of intersection of plating with longitudinal (I). (Feet)
XLONGL(I,2)	Height above keel of plating-longitudinal intersection. (Feet)
XLONGL(I,3)	Half breadth of point preceding the intersection. (Feet)
XLONGL(I,4)	Height above keel of point preceding the intersection. (Feet)

Symbol	Meaning
W5BACT	Tolerable longitudinal spacing for selected plating thickness. (Feet)
W5BPRC	Longitudinal span to longitudinal in question. (Feet)
W5BTOL	Permissible spacing to next longitudinal. (Feet)
SUMDST/DSTSUM/ DSUM	Sum of distances between points on girth. (Feet)
SUMCAL/SUMDIF	Distance to point preceding plating-longitudinal intersection. (Feet)
DIFF	Distance from point at SUMCAL/ SUMDIF to the intersection. (Feet)
ILONGL	An identifying number for longitudinals other than the keel. No. 1 adjacent to the keel.
ICOUNT	The value of ILONGL at deck-shell intersection. No longitudinal here.
SPAN(I)	Distance <u>to</u> longitudinal (I) from preceding longitudinal. (Feet)
BBDIST	Distance needed to be gained by reducing spans between shell longitudinals to permit W5BMIN distance from last shell longitudinal to deck intersection. (Feet)
STEP	Increment the span between longitudinals is reduced. (Feet)
IDIFF	Number of spans to be reduced on deck to obtain desired span at centerline.
AAA	Effective width of plating. (In.)
FF	Moment of longitudinal-plating combination about outer edge of the plating. ($In.^3$)
FFF	Total area of the longitudinal-plating combination. ($In.^2$)

Symbol	Meaning
CGCG(I)	Centroid of longitudinal - plating combination, in web axis. (In.)
XMINER(I)	Moment of inertia of longitudinal-plating combination about CGCG(I). ($In.^4$)
RGYR	Radius of gyration of longitudinal-plating combination. (In.)
EFSPAN	Effective span (supports fixed) for stiffener strength calculation . (Feet)
DVALUE	Flexural rigidity of plating. (Ton-In.)
STALL	Permissible sum of primary and secondary stresses. ($Tons/In.^2$)
ARM	Distance to outermost fiber of longitudinal-plating combination from CGCG(I). (Inches)
PRESS	Hydrostatic pressure at longitudinal. ($Tons/In.^2$)
BMOMNT	Maximum bending moment on the longitudinal-plating combination at mid-span. (Ton-In.)
ST1EST	Estimated primary stress. ($Tons/In.^2$)
ST2ALL	Allowable value of secondary stress. ($Tons/In.^2$)
REQMOD	Required section modulus of plating-longitudinal combination. ($In.^3$)
SMODMN(I)	Required section modulus for longitudinal (I)-plating combination at determined by subroutine CLONGL. ($In.^3$)
BVALUE	Rigidity. (EI) ($Ton-In.^2$)
BETA	Aspect ratio of plate.
GAMMA	Inertia factor.
DELTA	Area factor.

Symbol	Meaning
SUMTN	Intermediate value used in calculating critical strength of stiffened plating. (Tons/In.^{2})
BETAPL	Used in calculating critical strength of stiffened plating. (BETA^2 + 1)
CRITST	Design stress criteria. (Tons/In.^{2}) (1.25 x (ST1EST + ST2EST))
TOLSTR	Tolerable stress level determined by critical strength calculation. (Tons/In.^{2})
AREAPT	Total cross section area of half breadth plating. (In.^{2})
XLNGTL(1,I)	Characteristics of keel longitudinal.
XLNGTL(2,I)	Characteristics of other longitudinals.
SLOPE2(K)	Slope of the web of longitudinal (K).
ZZZ	Height of VCG of longitudinal above longitudinal-plating intersection. (Feet)
ZPOINT	Height of VCG of longitudinal above the base line. (Feet)
BASEMT(K)	Height of VCG of longitudinal above the base line. (Feet) K = 1 Keel K = 2,...40 (LONGL 1,...39)
BLMOM	Total moment about the base line. (In.^{2} Feet)
XMOMIN	Total moment of inertia about the base line. (In.^{2} Feet^2)
XINER	Moment of inertia of the midship section about the neutral axis. (In.^{2} Feet^2)
ATHL	Plating thickness found to be insufficient, to be incremented. (Inches)

Output

Symbol	Meaning
WEIGHT	Weight contribution of the plating. (Pounds/Ft. length)

Symbol	Meaning
ZNAXIS	Height of neutral axis of midship section above base line. (Feet)
REQMIN	Required moment of inertia about original DD-931 neutral axis. ($In.^2$ $Ft.^2$)
ASTRSS	Actual primary compressive stress in keel. ($Tons/In.^2$)
BSTRESS	Actual primary compressive stress in deck. ($Tons/In.^2$)
WTOTLB	Total structural weight. (Pounds/ Ft. length)
WFRAME	Transverse frame weight. (Pounds/ Ft. length)
WTOTAL	Total weight. (Tons/Ft. length)
WLONGL	Total longitudinal weight. (Pounds/ Ft. length)

Sample Input/Output (Refer to printout of typical computer run, following pages)

Fundamental Equations (Refer to program listing, following pages, and St. Denis [1])

THE FOLLOWING IS A REPRESENTATIVE SAMPLING OF EQUATIONS PARTICULARLY IMPORTANT TO MAIN PROGRAM RUNSCORE:

Longitudinal location

SUMDST = SUMDST + PTDATA(I,J,3)

SUMCAL = SUMDST - PTDATA(I,J,3)

DIFF = W5BPRC - SUMCAL

$$XLONGL(ILONGL,1) = PTDATA(I,J,1) + \frac{DIFF \times (PTDATA(I,J+1,1) - PTDATA(I,J,1))}{PTDATA(I,J,3)}$$

XLONGL(ILONGL,3) = PTDATA(I,J,1)

Satisfy requirements as to minimum radius of gyration

AAA = lesser, 12. x SPAN(I) or 50. x TH1

$$FF = XLGTNL(J,3) \times (XLGTNL(J,4) + TH1) + 0.5 \times AAA \times (TH1^2)$$

$$FFF = XLGTNG(J,3) + TH1 \times AAA$$

$$CGCG(I) = FF / FFF$$

$$XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3) \times (XLGTNL(J,4) - CGCG(I))^2 + 0.08333 \times AAA \times TH1^3 + TH1 \times AAA \times (CGCG(I) - 0.5 \times TH1)^2$$

$$RGYR = \sqrt{\frac{XMINER(I)}{FFF}}$$

Satisfy requirements as to stiffener strength

$$EFSPAN = 12. \times 0.577 \times FRM$$

$$DVALUE = \frac{13392.857 \times TH1^3}{10.8}$$

$$BMOMNT = 216. \times PRESS \times SPAN(I) \times FRM^2$$

$$REQMOD = BMOMNT / ST2ALL$$

$$BVALUE = 13392.857 \times XMINER(I)$$

$$GAMMA = \frac{BVALUE}{12. \times SPAN(I) \times DVALUE}$$

$$DELTA = \frac{XLGTNL(J,3)}{12. \times SPAN(I) \times TH1}$$

$$SUMTN = \frac{3.1416^2 \times DVALUE}{144. \times TH1 \times SPAN(I)^2}$$

$$BETAPL = 1.0 + BETA^2$$

$$CRITST = 1.25 \times (ST1EST + ST2EST)$$

$$TOLSTR = \frac{SUMTN \times (BETAPL^2 + 4. \times GAMMA)}{BETA^2 \times (1. + 4. \times DELTA)}$$

Calculate the total moment of inertia of the midship section

$$ADINER = XLNGTL(1,3) \times BASEMT(K)^2 + XLNGTL(1,2)/144. + (XLNGTL(1,1) - XLNGTL(1,2))^2 \times 2. \times \left|\frac{Arctan(SLOPE2(K))}{144. \times 3.1416}\right|$$

$$XINER = \left|\frac{ZNAXIS \times (BLMOM^2 - AREAPT \times XMOMIN)}{BLMOM}\right|$$

<u>Add in the weight contribution of the main transverse frames</u>

$$WTOTLB = 3.4 \times AREAPT + \frac{2859. \times (1. + (0.833 \times (FRM - 8)/8))}{FRM}$$

<u>Sample Calculation</u> (Refer to program listing, flow chart, and printout of typical computer run, following pages)

```
      DIMENSION XLONGL(40,4),SPAN(40),SMODMN(40),XLGTNL(9,5),XLNGTL(2,5)
     1,CGCG(40),XMINER(40),SLOPE2(40),PTDATA(30,10,3),BASEMT(40)
C
C     INPUT DATA AND INITIALIZE STORAGE VALUES
C
      W5BACT = 0.0
  954 FORMAT ('1       I       J        PTDATA(I,J,1)     PTDATA(I,J,2)
     1  PTDATA(I,J,3)')
  951 FORMAT (4X,I4,4X,I4,7X,3(F10.6,5X))
      WRITE (6, 954)
  901 FORMAT (23X,4(2X,F10.6))
      DO 907 I = 1,29
      DO 907 J = 1,10
  907 READ (5,901) PTDATA(I,J,1), PTDATA(I,J,2),PTDATA(I,J,3)
      DO 903 I = 1, 40
      DO 903 J = 1, 4
  903 XLONGL(I,J) = 0.0
      DATA XL1BP,SUMDST,ILONGL,R5GYRA,W5BTOL/407.,0.,1,0.,0./
      I = 30
      J = 1
      READ (5,901)  PTDATA(I,J,1), PTDATA(I,J,2), PTDATA(I,J,3)
      DO 910 J = 2, 10
      DO 910 K = 1, 3
  910 PTDATA(I,J,K) = 0.0
      DO 941 J = 1, 2
      DO 941 K = 1, 5
  941 XLNGTL(J,K) = 0.0
  900 FORMAT (5F16.7)
  915 FORMAT ('1  REQUIRED MOMENT OF INERTIA =',F20.6,' IN**2  FT**2')
  916 FORMAT ('0  ACTUAL MOMENT OF INERTIA =',F20.6,' IN**2  FT**2')
  917 FORMAT ('0  MAX. TOLERABLE ST1CRK =',F10.7,' TONS PER SQ. INCH')
  918 FORMAT ('0  ACTUAL ST1CRK =',F10.7,' TONS PER SQ. INCH')
  919 FORMAT ('0  MAX. TOLERABLE ST1CRD =',F10.7,'TONS PER SQ. INCH')
  920 FORMAT ('0  ACTUAL ST1CRD =',F10.7,' TONS PER SQ. INCH')
  921 FORMAT ('0  TOTAL WEIGHT =', F10.7,' TONS PER FOOT LENGTH')
 1921 FORMAT ('0        PLATING WEIGHT =', F15.7,' POUNDS PER FOOT LENGTH'
     1)
 1922 FORMAT ('         LONGITUDINAL WEIGHT =', F15.7,' POUNDS PER FOOT LE
     1NGTH')
 1923 FORMAT ('         TRANSVERSE FRAME WEIGHT =',F15.7,' POUNDS PER FOOT
     1 LENGTH')
  922 FORMAT ('0  TOTAL WEIGHT =', F15.7,' POUNDS PER FOOT LENGTH')
  923 FORMAT ('0  NEUTRAL AXIS IS ',F10.7,' FEET ABOVE BASE LINE')
  924 FORMAT ('0      DESIGN IS ACCEPTABLE')
  934 FORMAT ('0     SPAN(',I2,')  =',F10.6)
  933 FORMAT ('1     SPAN(',I2,')  =',F10.6)
  925 FORMAT ('0        DESIGN REPEATED WITH TH1 INCREASED')
  926 FORMAT ('0        DESIGN IS NOT POSSIBLE UNLESS TH1 IS GREATER THAN
```

```
      1 ONE INCH.')
  928 FORMAT ('0  SCANTLING ',I3,'  SELECTED--CROSS-SECTION AREA IS',F1
     10.7,'  SQ. IN. AND WEB DEPTH IS ',F10.7,' INCHES.')
  929 FORMAT('0  KEEL HAS AN AREA OF',F10.7,' SQ. IN. AND A WEB DEPTH OF
     1 ',F10.7,' INCHES.')
      DO950 I = 1, 30
      DO 950 J = 1, 10
  950 WRITE(6,951) I,J,PTDATA(I,J,1),PTDATA(I,J,2),PTDATA(I,J,3)
      READ (5,900)  ST1CRK, ST1CRD, ST2EST, SGMULT, SGMYLD
  955 FORMAT ('0     INTERIM TH1 =',F10.6,' AND W5BACT =',F10.6)
  956 FORMAT ('      I =',I3,'     J =',I3,'      SUMDST =',F10.6)
  957 FORMAT ('0  SPAN(',I2,')  = ',F10.6,'    I = ',I2,'  J = ',I2)
  958 FORMAT ('0     I = ', I3,'     HM = ', F10.6)
  959 FORMAT ('0     XMINER(',I2,') ='    F15.6)
  960 FORMAT ('0     CGCG(',I2,')  = ', F10.6)
  961 FORMAT ('0     LONGITUDINAL (', I2,')  IS SELECTED')
  962 FORMAT ('0     BASEMT(', I2,')  = ',F10.6)
  963 FORMAT ('0     SELECTED PLATING THICKNESS = ',F10.6,' INCHES.  ')
      READ (5,900)  A3HEEL, D1, H1AMDK, H1DFL
  902 FORMAT (1H1,6X,'ST1CRK',9X,'ST1CRD',9X,'ST2EST',9X,'SGMULT',9X,
     1 'SGMYLD')
  904 FORMAT (5(5X,F10.6))
  905 FORMAT (5X,'W5BMIN  =',F10.6,'    FRM  =',F10.6)
  911 FORMAT (I3,6(2X,F13.6))
  912 FORMAT ('1I',4X,'      Y     ',5X,'     Z     ',5X,'    YPR    ',
     1 5X,'     ZPR    ',7X,'SPAN(I)',7X,'SMODMN(I)')
  913 FORMAT (5F16.7)
  964 FORMAT ('0  I     MAX. I.       MIN. I.         AREA           VCG
     1      DEPTH')
  975 FORMAT (2X, I2, 2X,F11.6, 4(3X,F10.6))
      WRITE (6, 964)
      DO 914 I = 1, 9
      READ (5,913) XLGTNL(I,1),XLGTNL(I,2),XLGTNL(I,3),XLGTNL(I,4),XLGTN
     1L(I,5)
  914 WRITE (6,975) I, XLGTNL(I,1), XLGTNL(I,2), XLGTNL(I,3), XLGTNL(I,4
     1), XLGTNL(I,5)
  965 FORMAT('0  W5BACT =',F10.6,'    W5BPRC =',F10.6,'    W5BTOL =',F10.6
     1)
  966 FORMAT('0    Y =',F10.6,'  Z =',F10.6,'  YPR =',F10.6,'  ZPR =',F10
     1.6)
  967 FORMAT ('0   CLONGL OUTPUT = ',4(F10.6,5X))
C
C     PROVIDE INPUT DATA TO CONTINUE CALCULATION INTERRUPTED IN PREVIOUS
C     COMPUTER RUN.   SOLUTION UP TO THIS TIME INDICATED FURTHER INCREMENTS
C     IN PLATING THICKNESS WERE NECESSARY.
C
  500 READ (5, 900) W5BMIN, FRM
      IF (W5BMIN .GT.  9.99)  GO TO 420
```

```
      W5BACT = 0.0
  400 WRITE  (6, 902)
      SUMDST = 0.0
      ILONGL = 1
      W5BTOL = 0.0
      IF (W5BACT .GT. 0.0) GO TO 668
C
C     DETERMINE PLATING THICKNESS
C
      CALL TSLECT (W5BMIN,ST1CRK,ST2EST,SGMULT,FRM,TH1,W5BACT)
      GO TO 667
  668 W5BACT = TH1 * W5BACT / ATH1
  667 DO 940 J = 1, 40
      SPAN(J) = 0.0
      SMODMN (J) = 0.0
      CGCG(J) = 0.0
      XMINER(J) = 0.0
      SLOPE2(J) = 0.0
  940 BASEMT(J) = 0.0
      DO 9940 J = 1, 40
      DO 9940 K = 1, 4
 9940 XLONGL(J,K) = 0.0
      WRITE (6,904) ST1CRK,ST1CRD,ST2EST,SGMULT,SGMYLD
      WRITE (6, 905) W5BMIN, FRM
      WRITE (6, 955)  TH1, W5BACT
      W5BPRC = W5BACT
      WRITE (6,965) W5BACT,W5BPRC,W5BTOL
C
C     DETERMINE ACCEPTABLE LONGITUDINAL SPACING FOR BOTH DECK AND SIDE
C     SHELL LONGITUDINALS.
C
  226 DO 200 I - 1, 30
      DO 200 J = 1, 10
      IF (ILONGL .GT. 1) GO TO 333
      W5BPRC = W5BACT
      GO TO 115
  333 W5BPRC = W5BTOL
  115 SUMDST = SUMDST + PTDATA (I, J, 3)
      WRITE (6, 956) I, J, SUMDST
      IF (I .EQ. 30) GO TO 225
      IF (I .EQ. 19) GO TO 205
      GO TO 207
  205 IF (J .EQ. 10) GO TO 204
  207 IF ((SUMDST - W5BPRC) .GT. 0.0) GO TO 201
      GO TO 200
  201 SUMCAL = SUMDST - PTDATA(I,J,3)
      DIFF = W5BPRC - SUMCAL
C
```

```
C     LOCATE THE LONGITUDINALS
C
      IF (J .EQ. 10) GO TO 202
      XLONGL(ILONGL,1)    = PTDATA(I,J,1) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I,J+1,1) - PTDATA(I,J,1))
      XLONGL(ILONGL,2)= PTDATA(I,J,2) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I,J+1,2) - PTDATA(I,J,2))
      XLONGL(ILONGL, 3) = PTDATA (I, J, 1)
      XLONGL(ILONGL, 4) = PTDATA (I, J, 2)
      SUMDST = SUMDST - W5BPRC
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),X
     1LONGL(ILONGL,4)
      GO TO 203
  202 XLONGL(ILONGL,1)= PTDATA(I,J,1) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I+1,1,1) - PTDATA(I,J,1))
      XLONGL(ILONGL,2) = PTDATA(I,J,2) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I+1,1,2) - PTDATA(I,J,2))
      XLONGL(ILONGL,3) = PTDATA(I,J,1)
      XLONGL(ILONGL, 4) = PTDATA (I, J, 2)
      SUMDST = SUMDST - W5BPRC
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),X
     1LONGL(ILONGL,4)
C
C     CALCULATE  R5GYRA  AND  SMODMN  REQUIRED FOR LONGITUDINALS
C
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
  203 AAA = R5GYRA
      CALL CLONGL(ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,W5BPRC,
     1 R5GYRA,SMODMN(ILONGL),XLONGL(ILONGL,1),XLONGL(ILONGL,2))
      WRITE (6, 967) R5GYRA,SMODMN(ILONGL),XLONGL(ILONGL,1),XLONGL(ILONG
     1L,2)
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
      IF (R5GYRA .GT. AAA) GO TO 210
      R5GYRA = AAA
C
C     DETERMINE LONGITUDINAL SPACING.
C
  210 CALL CSPACE (ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,
     1 XLONGL(ILONGL,1),XLONGL(ILONGL,2),W5BPRC,W5BTOL)
      SPAN(ILONGL) = W5BPRC
      WRITE (6, 957) ILONGL, SPAN(ILONGL),I, J
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
      ILONGL = ILONGL + 1
      GO TO 200
C
C     ADJUST FOR DECK-SHELL INTERSECTION.
C
  204 ICOUNT = ILONGL
```

```
      IF (SUMDST .LT. W5BMIN) GO TO 208
      SPAN (ILONGL) = SUMDST
      WRITE (6, 957) ILONGL, SPAN(ILONGL), I, J
      SUMDST = 0.0
      XLONGL (ILONGL,1) = PTDATA(20, 1, 1)
      XLONGL (ILONGL,2) = PTDATA(20, 1, 2)
      XLONGL (ILONGL,3) = PTDATA(20, 1, 1)
      XLONGL (ILONGL,4) = PTDATA(20, 1, 2)
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),
     1 XLONGL(ILONGL,4)
      ILONGL = ILONGL + 1
      GO TO 200
  208 XX = ILONGL - 1
      BBDIST = W5BMIN - SUMDST
      STEP = BBDIST / XX
  214 JJ = 1
      IF ((SPAN(1) - W5BMIN) .GT. STEP) GO TO 216
C
C     ADJUST SPACING BY REDUCING THE SPAN.
C
      DO 98 JAJA=1, ILONGL
      CC = SPAN(JAJA) - W5BMIN
      BBDIST = BBDIST - CC
      IF (BBDIST .LT. 0.0) GO TO 97
   98 SPAN (JAJA) = W5BMIN
      WRITE (6, 957) JAJA, SPAN(JAJA), I, J
      IF (JAJA .EQ. ILONGL) GO TO 99
   97 SPAN (JAJA) = SPAN (JAJA) - CC - BBDIST
      WRITE (6, 957) JAJA, SPAN(JAJA), I, J
   99 STEP = 0.0
  216  DSTSUM = 0.0
  999 DO 215 IA = 1, 19
      DO 215 JA = 1, 10
      DSTSUM = DSTSUM + PTDATA (IA,JA,3)
      IF ((10*IA + JA) .EQ. 200) GO TO 110
      IF((SPAN(JJ) - DSTSUM) .LT. 0.0) GO TO 107
      GO TO 215
  107 SPAN(JJ) = SPAN(JJ) - STEP
      SUMDIF = DSTSUM - PTDATA(IA,JA,3)
      DIFF = SPAN(JJ) - SUMDIF
      WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      IF (SPAN(JJ) .GT. 0.0) GO TO 127
      SPAN(JJ) = 0.0
       WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      GO TO 110
  127 IF (JA .EQ. 10) GO TO 108
      XLONGL(JJ,1) = PTDATA(IA,JA,1)    +    (  DIFF    /
     1 PTDATA (IA,JA,3)) * (PTDATA(IA,JA+1,1) - PTDATA(IA,JA,1))
```

```
      XLONGL(JJ,2) =     PTDATA(IA,JA,2)    +    ( DIFF /
     1 PTDATA(IA,JA,3)) * (PTDATA(IA,JA+1,2) - PTDATA(IA,JA,2))
      XLONGL(JJ,3)= PTDATA (IA, JA, 1)
      XLONGL(JJ,4)= PTDATA (IA, JA, 2)
      WRITE(6,966)XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      DSTSUM = DSTSUM - SPAN(JJ)
      JJ = JJ + 1
      GO TO 215
  108 XLONGL(JJ,1) = PTDATA(IA,JA,1)    +     (   DIFF    /
     1 PTDATA(IA,JA,3)) * (PTDATA(IA+1,1,1) - PTDATA(IA,JA,1))
      XLONGL(JJ,2) =     PTDATA(IA,JA,2)    +    ( DIFF /
     1 PTDATA(IA,JA,3))*(PTDATA(IA+1,1,2) - PTDATA(IA,JA,2))
      XLONGL(JJ,3)= PTDATA(IA,JA,1)
      XLONGL(JJ,4) = PTDATA(IA,JA,2)
      WRITE (6, 966) XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      DSTSUM = DSTSUM - SPAN(JJ)
      JJ = JJ + 1
      GO TO 215
  110 XLONGL(JJ,1)= PTDATA (20,1,1)
      XLONGL(JJ,2) = PTDATA(20,1,2)
      XLONGL(JJ,3)= PTDATA (20,1,1)
      XLONGL(JJ,4)= PTDATA (20, 1, 2)
      SPAN(ILONGL) = W5BMIN
      WRITE (6, 966) XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      ILONGL = ILONGL + 1
      SUMDST = 0.0
      GO TO 200
  215 CONTINUE
C
C     ADJUST DECK LONGITUDINAL SPACING TO FACILITATE SYMMETRY RELATIVE
C     TO THE CENTER LINE.
C
  225 IF (((0.5 * W5BMIN) - SUMDST) .GT. 0.0) GO TO 801
      GO TO 220
C
C     DECREASE SPAN TO OTHER DECK LONGITUDINALS TO PERMIT CENTERING SPAN
C     ON THE CENTERLINE.
C
  801 IDIFF = ILONGL - ICOUNT - 1
      XDIFF = IDIFF
      STEP = (0.5 * W5BMIN - SUMDST) / XDIFF
      SPAN(ILONGL) = 0.5 * W5BMIN
      ILONGL = ILONGL - 1
      IRKED = ICOUNT + 1
      DO 826 IA = IRKED, ILONGL, 1
      SPAN(IA) = SPAN(IA) - STEP
  826 WRITE (6,957) IA, SPAN(IA),II,JJ
```

```
      ILONGL = ILONGL + 1
      IA = ICOUNT + 1
      DO 227 II = 20, 29
      DO 227 JJ = 1, 10
      DSUM = DSUM + PTDATA(II,JJ,3)
      IF ((SPAN(IA) - DSUM) .LT. 0.0) GO TO 228
      GO TO 227
  228 IF (JJ .EQ. 10) GO TO 229
      SUMDIF = DSUM - PTDATA(II,JJ,3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4)= PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
      GO TO 227
  229 SUMDIF = DSUM - PTDATA (II, JJ, 3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4) = PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
  227 CONTINUE
      GO TO 300
  220 IF (SUMDST .GT. W5BMIN) GO TO 221
C
C     DECREASE SPANS TO OTHER DECK LONGITUDINALS TO PERMIT PLACING A
C     LONGITUDINAL ON THE DECK CENTERLINE.
C
      IF (SUMDST .LT. 0.5*W5BTOL) GO TO 520
      BBDIST = W5BMIN - SUMDST
      IA = ILONGL - ICOUNT - 1
      XIA = IA
      SPAN(ILONGL) = W5BMIN
      STEP = BBDIST / XIA
      ICOUNT = ICOUNT + 1
      DO 230 IAI = ICOUNT, ILONGL
  230 SPAN (IAI) = SPAN (IAI) - STEP
      ICOUNT = ICOUNT - 1
```

```
      WRITE (6, 957) IAI, SPAN(IAI), II, JJ
      IA = ICOUNT
      DO 237 II = 20, 29
      DO 237 JJ = 1, 10
      DSUM = DSUM + PTDATA(II,JJ,3)
      IF ((SPAN(IA) - DSUM) .LT. 0.0) GO TO 238
      GO TO 237
  238 IF (JJ .EQ. 10) GO TO 239
      SUMDIF = DSUM - PTDATA (II, JJ, 3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4) = PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
      GO TO 237
  239 SUMDIF = DSUM - PTDATA (II, JJ, 3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4)= PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
  237 CONTINUE
      GO TO 300
C
C     SPAN GREATER THAN W5BMIN, PLACE LONGITUDINAL ON THE CENTERLINE.
C
  221 SPAN(ILONGL) = SUMDST
      XLONGL(ILONGL,1) = PTDATA(30,1, 1)
      XLONGL(ILONGL,2) = PTDATA(30, 1, 2)
      XLONGL(ILONGL,3) = PTDATA(30,1, 1)
      XLONGL(ILONGL,4) = PTDATA(30, 1, 2)
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),
     1 XLONGL(ILONGL,4)
      GO TO 300
C
C     CURRENT LONGITUDINAL PLACEMENT OK.  CENTER SPAN ON CENTERLINE.
C
  520 SPAN(ILONGL) = SUMDST
```

```
      GO TO 300
  200 CONTINUE
C
C     CALCULATE THE REQUIRED LONGITUDINAL SCANTLING.
C
  300 DO 310 I = 1, 5
  310 XLNGTL(1,I) =XLGTNL(9,I)
      WRITE (6, 912)
      DO 206 III = 2, 40
      IF (SPAN(III) .GT. 0.0) GO TO 206
      SPAN(III) = 0.0
      IF (SPAN(III - 1) .GT. 0.0) GO TO 206
      XLONGL(III,1) = 0.0
      XLONGL(III,2) = 0.0
      XLONGL(III,3) = 0.0
      XLONGL(III,4) = 0.0
  206 WRITE(6,911) III,XLONGL(III,1),XLONGL(III,2),XLONGL(III,3),
     1 XLONGL(III,4),SPAN(III),SMODMN(III)
C
C     SATISFY REQUIREMENTS AS TO MINIMUM RADIUS OF GYRATION.
C
      J = 1
      DO 320 I = 1, 40
      IF (SPAN(I) .EQ. 0.0) GO TO 323
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 323
      IF (12.0*SPAN(I) .GT. 50.*TH1) GO TO 322
      AAA = 12.0 * SPAN(I)
      GO TO 321
  322 AAA = 50.*TH1
  321 FF = (XLGTNL(J,4) + TH1) * XLGTNL(J,3) + 0.5 * AAA * (TH1**2)
      FFF = XLGTNL(J,3) + TH1 * AAA
      CGCG(I) = FF/FFF
      WRITE (6, 960) I, CGCG(I)
      XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      RGYR = SQRT (XMINER(I) / FFF)
      WRITE (6, 961) J
      IF(R5GYRA .LT. RGYR) GO TO 320
      J = J + 1
      GO TO 321
  320 CONTINUE
C
C     SATISFY REQUIREMENTS AS TO STIFFENER STRENGTH.
C
  323 EFSPAN = 0.577 * FRM * 12.0
      DVALUE  = (13392.857 * (TH1**3)) / 10.8
      STALL = 38000. / 2240.
      DO 324 I = 1, 40
```

```
      IF (SPAN(I) .EQ. 0.0) GO TO 453
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 453
  329 IF(((XLGTNL(J,5) + TH1) - CGCG(I)) .LT. CGCG(I)) GO TO 325
      ARM = CGCG(I)
      GO TO 326
  325 ARM = XLGTNL(J,5) + TH1 - CGCG(I)
  326 IF (12.0*SPAN(I) .GT. 50.*TH1) GO TO 327
      AAA = 12.0 * SPAN(I)
      GO TO 328
  327 AAA = 50.0 * TH1
  328 CALL HDWTR(A3HEEL,XLONGL(I,1),D1,H1AMDK,H1DFL,NBELTS,XL1BP,
     1 XLONGL(I,2),HM)
      WRITE (6, 958) I, HM
      PRESS = 0.445 * HM/2240.
       BMOMNT = 216. * PRESS * SPAN(I) * FRM**2
      ST1EST = 7.93 * ABS(XLONGL(I,2)-((7.93/13.93)*26.23125))
      ST2ALL = STALL - ST1EST
      REQMOD = BMOMNT / ST2ALL
      XMINER(I)=XLGTNL(J,1)+XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      WRITE (6, 961) J
      IF((XMINER(I)/ARM).LT.SMODMN(I)) GO TO 1324
      IF ((XMINER(I)/ARM) .GT. REQMOD) GO TO 324
 1324 J = J + 1
      WRITE (6, 961) J
      GO TO 329
  324 CONTINUE
C
C     SATISFY REQUIREMENTS AS TO STIFFENER CRITICAL STRENGTH.
C
  453 DO 330 I = 1, 40
      IF (SPAN(I) .EQ. 0.0) GO TO 451
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 451
  336 IF (12.*SPAN(I) .GT. 50.*TH1) GO TO 337
      AAA = 12.0 * SPAN(I)
      GO TO 338
  337 AAA = 50.0 * TH1
  338 XMINER(I)=XLGTNL(J,1)+XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      BVALUE = 13392.857 * XMINER(I)
      BETA = FRM / SPAN(I)
      GAMMA = BVALUE / (SPAN(I) * 12. * DVALUE)
      DELTA = XLGTNL(J,3) / (12.0 * SPAN(I) * TH1)
      SUMTN = ((3.1416**2)*DVALUE)/(144. * TH1 * SPAN(I)**2)
      BETAPL = 1.0 + BETA**2
      ST1EST = 7.93* ABS(XLONGL(I,2)-((7.93/13.93)*26.23125))
      CRITST = 1.25 * (ST1EST + ST2EST)
      TOLSTR = SUMTN * (BETAPL**2 + 4.0*GAMMA)/((BETA**2)*(1.0 +
```

```
     1 4.0 * DELTA))
      WRITE (6, 959) I, XMINER(I)
      IF (TOLSTR .GT. CRITST) GO TO 330
      J = J + 1
      WRITE (6, 961) J
      GO TO 336
  330 CONTINUE
  451 WRITE (6, 961) J
C
C     CALCULATE THE TOTAL MOMENT OF INERTIA OF THE MIDSHIP SECTION.
C
      CALL PMINER(TH1,BLMOM,AREAPT,XMOMIN,XINER)
      WEIGHT = 6.8 * AREAPT
      DO 335 I = 1, 5
  335 XLNGTL(2,I) = XLGTNL(J,I)
      K = 1
      SLOPE2(K) = (XLONGL(K,3)-XLONGL(K,1))/(XLONGL(K,2)-XLONGL(K,4))
      ZZZ = XLNGTL(1,4)*(-SLOPE2(K))/(12.*SQRT(1.+(SLOPE2(K)**2)))
      ZPOINT = XLONGL(K,2) + ZZZ
      BASEMT(K) = ZPOINT
      WRITE (6, 962) K, BASEMT(K)
      DO 340 K = 2, 40
      IF (K .GT. ILONGL) GO TO 810
      IF (XLONGL(K,2) .EQ. 0.0) GO TO 810
      IF (K .LT. ICOUNT) GO TO 1811
      IF (K .GT. ICOUNT) GO TO 1811
      BASEMT(K) = 0.0
      GO TO 340
 1811 CONTINUE
      SLOPE2(K) = (XLONGL(K,3)-XLONGL(K,1))/(XLONGL(K,2)-XLONGL(K,4))
      ZZZ = XLNGTL(2,4)*(-SLOPE2(K))/(12.*SQRT(1.+(SLOPE2(K)**2)))
      ZPOINT = XLONGL(K,2) + ZZZ
      BASEMT(K) = ZPOINT
  340 WRITE(6, 962) K, BASEMT(K)
  810 AREAPT = 2.0 * AREAPT
      BLMOM = BLMOM * 2.0
      XMOMIN = 2.0 * XMOMIN
      K = 1
      ADINER = XLNGTL(1,3)*BASEMT(K)**2 + XLNGTL(1,2)/144. + (XLNGTL(1,1
     1) - XLNGTL(1,2))*2.*ABS(ATAN(SLOPE2(K))/(144.*3.1416))
      XMOMIN = XMOMIN + ADINER
      BLMOM = BLMOM + BASEMT(K)*XLNGTL(1,3)
      AREAPT = AREAPT + XLNGTL(1,3)
      DO 350 K = 2, 40
      IF (XLONGL(K,2) .EQ. 0.0) GO TO 351
      IF (K .GT. ILONGL) GO TO 351
      ADINER = XLNGTL(2,3)*BASEMT(K)**2 + XLNGTL(2,2)/144. + (XLNGTL(2,1
     1) - XLNGTL(2,2))*2.*ABS(ATAN(SLOPE2(K))/(144.*3.1416))
```

```
      IF (K .EQ. ILONGL) GO TO 352
      IF (K .EQ. ICOUNT) GO TO 350
  353 XMOMIN = XMOMIN + 2.0 * ADINER
      BLMOM = BLMOM + 2.0 * BASEMT(K)*XLNGTL(2,3)
      AREAPT = AREAPT + 2.0 * XLNGTL(2,3)
      GO TO 350
  352 IF (XLONGL(ILONGL,1) .GT. 0.0) GO TO 353
      XMOMIN = XMOMIN + ADINER
      BLMOM = BLMOM + BASEMT(K) * XLNGTL(2, 3)
      AREAPT = AREAPT + XLNGTL(2, 3)
  350 CONTINUE
  351 ZNAXIS = BLMOM / AREAPT
      XINER = ABS (ZNAXIS*((BLMOM**2) - AREAPT*XMOMIN)/BLMOM)
      REQMIN = 74100. * 26.231247 / 13.93
      DO 807 KK = 1, 40
      IF (SPAN(KK) .GT. 0.0) GO TO 807
      SPAN(KK) = 0.0
  807 CONTINUE
      IR = 1
      WRITE (6, 933) IR, SPAN(IR)
      DO 600 IR= 2, 40
  600 WRITE (6, 934) IR, SPAN(IR)
  804 WRITE(6,912)
      DO 806 KK= 1, 40
  806 WRITE(6,911) KK,XLONGL(KK,1),XLONGL(KK,2),XLONGL(KK,3),
     1 XLONGL(KK,4),SPAN(KK),SMODMN(KK)
      WRITE (6,915) REQMIN
      WRITE (6,916) XINER
      WRITE (6,917) STICRK
      ASTRSS = 74100. * ZNAXIS / XINER
      WRITE (6,918) ASTRSS
      WRITE (6,919) STICRD
      BSTRSS = 54400. * (26.231247 - ZNAXIS) / XINER
      WRITE (6, 920) BSTRSS
C
C     ADD IN THE WEIGHT CONTRIBUTION OF THE MAIN TRANSVERSE FRAMES.
C
      WTOTLB = AREAPT * 3.4 + 2859.*(1.0 + (0.8333*(FRM-8.)/8.)) /
     1 (FRM)
      WFRAME = WTOTLB - 3.4 * AREAPT
      WTOTAL = WTOTLB / 2240.
      WRITE (6,921) WTOTAL
      WRITE (6,922) WTOTLB
      WRITE (6, 1921) WEIGHT
      WLONGL = WTOTLB - WEIGHT - WFRAME
      WRITE (6, 1922) WLONGL
      WRITE (6,1923) WFRAME
      WRITE (6, 923) ZNAXIS
```

```
      WRITE (6,928) J,XLNGTL(2,3),XLNGTL(2,5)
      WRITE (6,929) XLNGTL(1,3),XLNGTL(1,5)
      WRITE (6, 963) TH1
      IF (ST1CRK .LT. ASTRSS) GO TO 421
      IF (ST1CRD .GT. BSTRSS) GO TO 500
  421 ATH1 = TH1
      WRITE (6, 925)
      IF (TH1 - 0.5) 401, 402, 403
  402 TH1 = 0.625
      GO TO 400
  403 IF (TH1 - 0.875) 404, 405, 406
  405 TH1 = 0.9375
      GO TO 400
  406 IF(TH1 - 0.9375) 405,407,408
  407 TH1 = 1.0
      GO TO 400
  408 WRITE (6, 926)
      GO TO 420
  401 IF(TH1 - 0.3125) 409, 410, 411
  410 TH1 = 0.34375
      GO TO 400
  409 IF (TH1 - 0.28125) 412, 413, 410
  413 TH1 = 0.3125
      GO TO 400
  412 TH1 = 0.28125
      GO TO 400
  411 IF (TH1 - C.375) 414, 415, 416
  415 TH1 = 0.4375
      GO TO 400
  414 TH1 = 0.375
      GO TO 400
  416 TH1 = 0.500
      GO TO 400
  404 IF(TH1 - 0.75) 417, 418, 405
  418 TH1 = 0.875
      GO TO 400
  417 TH1 = 0.75
      GO TO 400
  420 STOP
      END
```

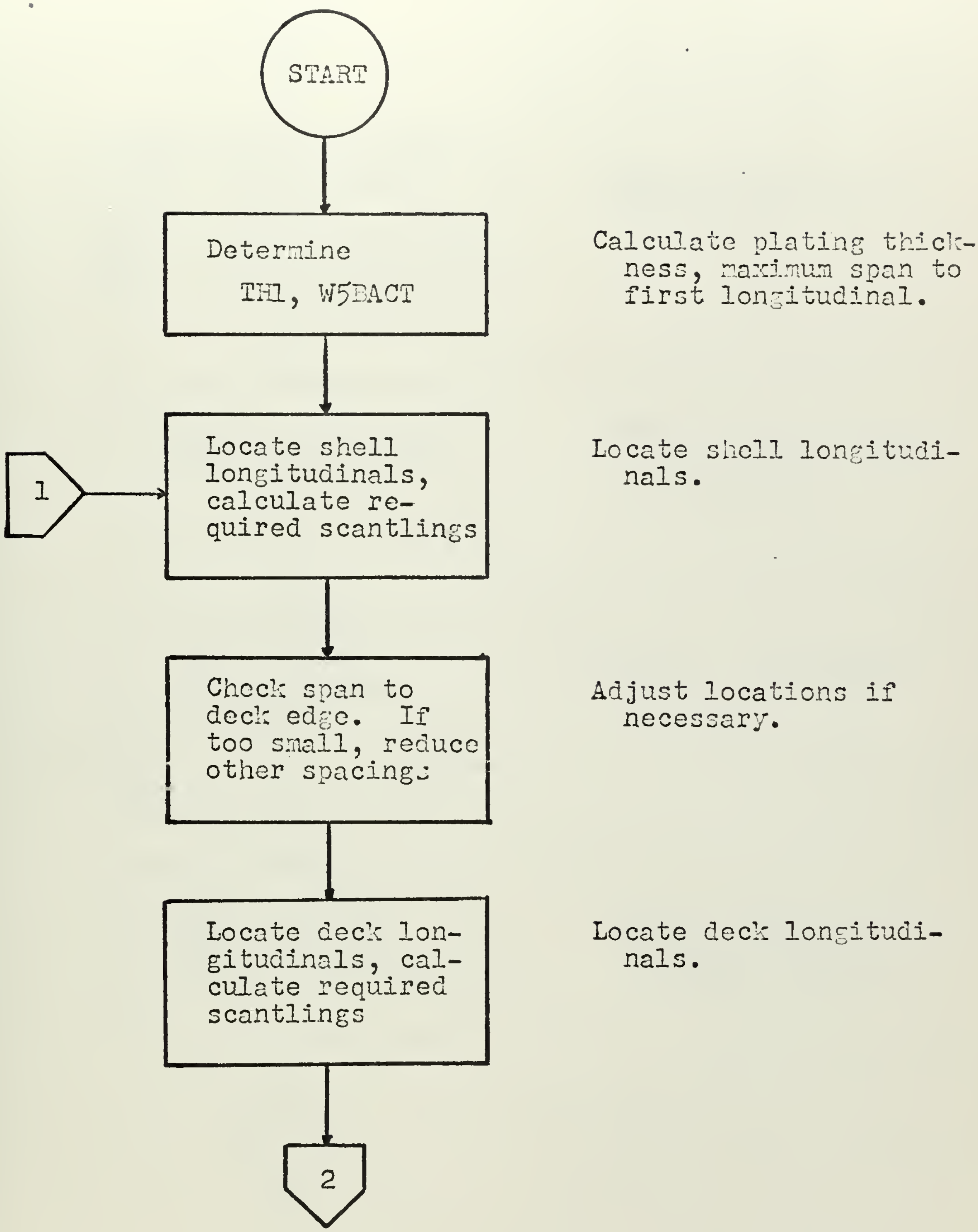


FIGURE III

MAIN PROGRAM <u>RUNSCORE</u> FLOW CHART

2

Check span to centerline. Either place long'l on centerline or have centerline at midspan. If necessary, reduce other spacings.

Adjust locations if necessary.

Select long'l to give needed radius of gyration

Satisfy requirements as to minimum radius of gyration.

Check for adequate stiffener strength

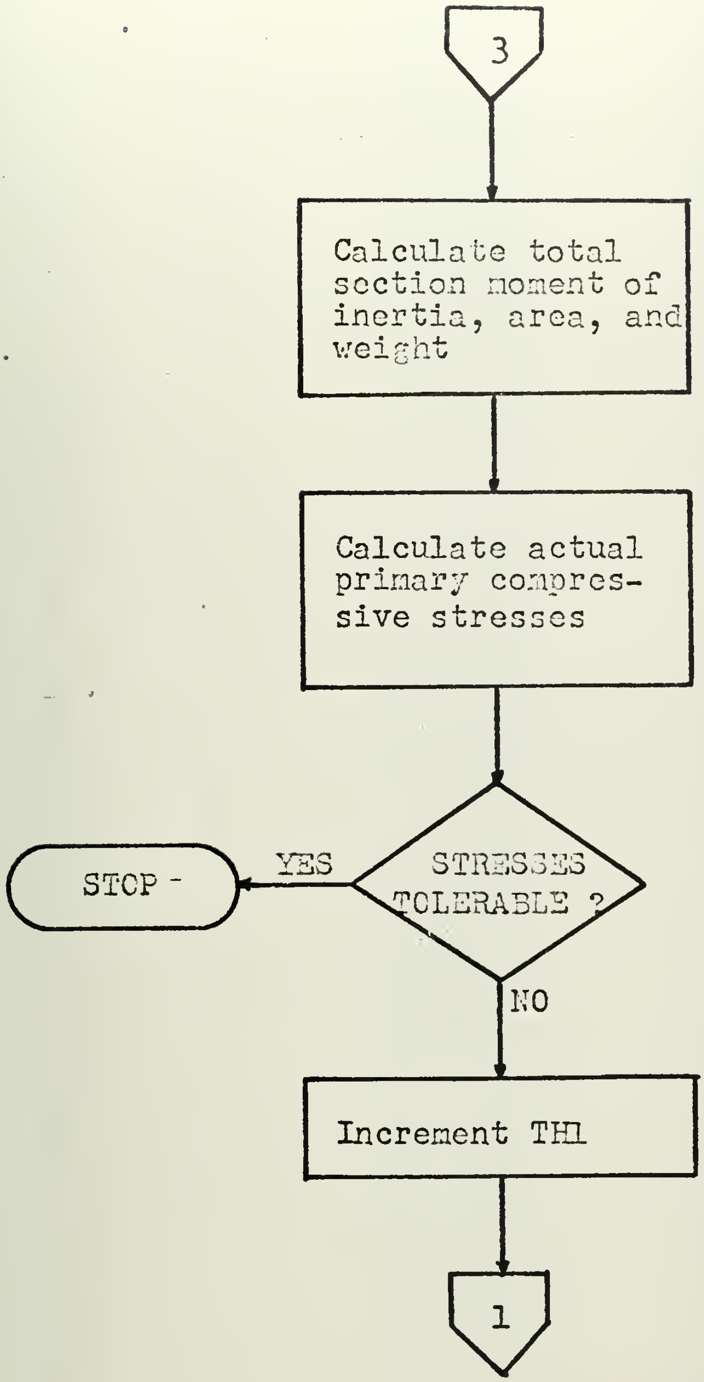
Satisfy requirements as to stiffener strength.

Check for adequate stiffener critical strength

Satisfy requirements as to stiffener critical strength.

3

FIGURE III - Continued



Check total section characteristics.

Check for adequacy of midship section.

If stresses are too great, increase plating thickness, repeat calculation.

FIGURE III - Continued

I	J	PTDATA(I,J,1)	PTDATA(I,J,2)	PTDATA(I,J,3)
1	1	0.0	0.0	0.200056
1	2	0.200000	0.004743	0.200057
1	3	0.400000	0.009515	0.200058
1	4	0.600000	0.014343	0.200060
1	5	0.800000	0.019255	0.200063
1	6	1.000000	0.024282	0.200067
1	7	1.200000	0.029449	0.200071
1	8	1.400000	0.034787	0.200075
1	9	1.599998	0.040322	0.200083
1	10	1.799997	0.046084	0.200092
2	1	2.000000	0.052099	0.200099
2	2	2.200000	0.058402	0.200110
2	3	2.400000	0.065033	0.200121
2	4	2.599998	0.072038	0.200138
2	5	2.799997	0.079464	0.200155
2	6	2.999997	0.087355	0.200177
2	7	3.199999	0.095758	0.200200
2	8	3.399999	0.104718	0.200227
2	9	3.599998	0.114281	0.200260
2	10	3.799996	0.124493	0.200300
3	1	4.000000	0.135401	0.400720
3	2	4.400000	0.159419	0.400908
3	3	4.799997	0.186407	0.401122
3	4	5.199999	0.216375	0.401354
3	5	5.599998	0.249332	0.401612
3	6	5.999996	0.285289	0.401894
3	7	6.399998	0.324254	0.402196
3	8	6.799995	0.366238	0.402525
3	9	7.199997	0.411250	0.402875
3	10	7.599997	0.459301	0.403255
4	1	8.000000	0.510412	0.403664
4	2	8.400000	0.564682	0.404182
4	3	8.799997	0.622685	0.404840
4	4	9.199999	0.685097	0.405653
4	5	9.599998	0.752593	0.406652
4	6	9.999996	0.825849	0.407861
4	7	10.399998	0.905538	0.409308
4	8	10.799995	0.992337	0.411031
4	9	11.199997	1.086922	0.413059
4	10	11.599997	1.189965	0.415431
5	1	12.000000	1.302128	0.203281
5	2	12.194790	1.360265	0.203980
5	3	12.389580	1.420801	0.204727
5	4	12.584370	1.483809	0.205523
5	5	12.779160	1.549357	0.206371
5	6	12.973948	1.617520	0.207274
5	7	13.168737	1.688371	0.208232
5	8	13.363527	1.761974	0.209250
5	9	13.558317	1.838410	0.210327
5	10	13.753109	1.917747	0.210916
6	1	13.947900	1.998631	0.224085
6	2	14.153110	2.088647	0.225563
6	3	14.358317	2.182284	0.227193
6	4	14.563527	2.279781	0.229008
6	5	14.768739	2.381433	0.230972
6	6	14.973948	2.487440	0.233151
6	7	15.179156	2.598112	0.235502
6	8	15.384368	2.713654	0.238073
6	9	15.589578	2.834351	0.240840
6	10	15.794765	2.960419	0.250581
7	1	16.000000	3.104218	0.141439
7	2	16.117676	3.182663	0.142650
7	3	[illegible]	[illegible]	[illegible]

7	4	16.353119	3.346128	0.145395
7	5	16.470810	3.431501	0.147028
7	6	16.588501	3.519608	0.149104
7	7	16.706238	3.611115	0.150991
7	8	16.823929	3.705704	0.153284
7	9	16.941620	3.803892	0.155638
7	10	17.059357	3.905701	0.150405
8	1	17.176529	4.000000	0.293348
8	2	17.391129	4.200000	0.287615
8	3	17.597809	4.400000	0.282204
8	4	17.796921	4.599998	0.277075
8	5	17.988678	4.799997	0.272213
8	6	18.173340	4.999997	0.267623
8	7	18.351166	5.199999	0.263299
8	8	18.522400	5.399999	0.259253
8	9	18.687378	5.599998	0.255442
8	10	18.846283	5.799996	0.252185
9	1	18.999878	6.000000	0.194464
9	2	19.115662	6.156250	0.192440
9	3	19.227997	6.312500	0.190448
9	4	19.336884	6.468750	0.188472
9	5	19.442261	6.625000	0.186540
9	6	19.544159	6.781250	0.184647
9	7	19.642563	6.937500	0.182745
9	8	19.737320	7.093750	0.180912
9	9	19.828522	7.250000	0.179094
9	10	19.916031	7.406250	0.176460
10	1	19.998047	7.562500	0.049333
10	2	20.020844	7.606250	0.049214
10	3	20.043381	7.650000	0.049094
10	4	20.065659	7.693748	0.048999
10	5	20.087723	7.737497	0.048896
10	6	20.109543	7.781247	0.048836
10	7	20.131241	7.824999	0.048767
10	8	20.152802	7.868749	0.048693
10	9	20.174164	7.912498	0.048647
10	10	20.195450	7.956246	0.049736
11	1	20.219101	8.000000	0.221883
11	2	20.315186	8.200000	0.221194
11	3	20.409668	8.400000	0.220430
11	4	20.502350	8.599998	0.219592
11	5	20.593018	8.799997	0.218688
11	6	20.681473	8.999997	0.217743
11	7	20.767563	9.199999	0.216706
11	8	20.850998	9.399999	0.215634
11	9	20.931595	9.599998	0.214540
11	10	21.009247	9.799996	0.213229
12	1	21.083176	10.000000	0.212228
12	2	21.154175	10.200000	0.211168
12	3	21.221924	10.400000	0.210194
12	4	21.286606	10.599998	0.209312
12	5	21.348343	10.799997	0.208509
12	6	21.407303	10.999997	0.207792
12	7	21.463669	11.199999	0.207150
12	8	21.517624	11.399999	0.206576
12	9	21.569336	11.599998	0.206064
12	10	21.618958	11.799996	0.205580
13	1	21.666504	12.000000	0.256441
13	2	21.723633	12.250000	0.255859
13	3	21.778061	12.500000	0.255320
13	4	21.829926	12.750000	0.254806
13	5	21.879181	13.000000	0.254342
13	6	21.925980	13.250000	0.253905
13	7	21.970337	13.500000	0.253502
13	8	22.012314	13.750000	0.253131
13	9	22.053003	14.000000	0.252791

13	10	22.089478	14.250000	0.252494
14	1	22.124878	14.500000	0.151348
14	2	22.145035	14.650000	0.151247
14	3	22.164429	14.799997	0.151147
14	4	22.183014	14.949999	0.151059
14	5	22.200882	15.099998	0.150970
14	6	22.217972	15.249996	0.150882
14	7	22.234253	15.399998	0.150799
14	8	22.249756	15.549995	0.150726
14	9	22.264542	15.699997	0.150649
14	10	22.278519	15.849997	0.150584
15	1	22.291733	16.000000	0.200665
15	2	22.308075	16.199997	0.200564
15	3	22.323166	16.399994	0.200475
15	4	22.337006	16.599991	0.200399
15	5	22.349686	16.799988	0.200334
15	6	22.361298	16.999985	0.200279
15	7	22.371933	17.199982	0.200235
15	8	22.381699	17.399979	0.200195
15	9	22.390610	17.599976	0.200165
15	10	22.398804	17.799973	0.200165
16	1	22.406235	18.000000	0.200118
16	2	22.413193	18.199997	0.200099
16	3	22.419571	18.399994	0.200080
16	4	22.425339	18.599991	0.200064
16	5	22.430527	18.799988	0.200049
16	6	22.435074	18.999985	0.200035
16	7	22.438965	19.199982	0.200023
16	8	22.442200	19.399979	0.200013
16	9	22.444748	19.599976	0.200006
16	10	22.446671	19.799973	0.200029
17	1	22.447342	20.000000	0.199998
17	2	22.447861	20.199997	0.199997
17	3	22.447678	20.399994	0.199999
17	4	22.446869	20.599991	0.200002
17	5	22.445450	20.799988	0.200006
17	6	22.443497	20.999985	0.200012
17	7	22.441010	21.199982	0.200019
17	8	22.438019	21.399979	0.200025
17	9	22.434647	21.599976	0.200033
17	10	22.430832	21.799973	0.200072
18	1	22.426590	22.000000	0.200047
18	2	22.422104	22.199997	0.200054
18	3	22.417328	22.399994	0.200060
18	4	22.412308	22.599991	0.200064
18	5	22.407120	22.799988	0.200068
18	6	22.401764	22.999985	0.200070
18	7	22.396378	23.199982	0.200073
18	8	22.390854	23.399979	0.200072
18	9	22.385376	23.599976	0.200071
18	10	22.379944	23.799973	0.200092
19	1	22.374878	24.000000	0.123975
19	2	22.371613	24.123932	0.123989
19	3	22.368378	24.247864	0.123988
19	4	22.365189	24.371811	0.124003
19	5	22.362015	24.495789	0.123986
19	6	22.358902	24.619736	0.123985
19	7	22.355820	24.743683	0.123970
19	8	22.352753	24.867615	0.123985
19	9	22.349701	24.991562	0.123985
19	10	22.346634	25.115494	0.124117
20	1	22.343796	25.239594	0.224005
20	2	22.120331	25.255127	0.223993
20	3	21.896866	25.270737	0.223976
20	4	21.673447	25.286301	0.223989
20	5	21.449997	25.301819	0.224005

20	6	21.226532	25.317333	0.223972
20	7	21.003098	25.332886	0.223988
20	8	20.779648	25.348404	0.223999
20	9	20.556183	25.363846	0.223983
20	10	20.332718	25.379303	0.223964
21	1	20.109299	25.394684	0.223978
21	2	19.885849	25.410030	0.223989
21	3	19.662369	25.425400	0.223956
21	4	19.438950	25.440674	0.223967
21	5	19.215500	25.455887	0.223981
21	6	18.992035	25.471085	0.223960
21	7	18.768570	25.486191	0.223940
21	8	18.545151	25.501236	0.223969
21	9	18.321686	25.516251	0.223947
21	10	18.098221	25.531174	0.223927
22	1	17.874802	25.546021	0.223937
22	2	17.651352	25.560776	0.223948
22	3	17.427887	25.575470	0.223911
22	4	17.204453	25.590088	0.223922
22	5	16.981003	25.604630	0.223932
22	6	16.757538	25.619080	0.223910
22	7	16.534073	25.633423	0.223887
22	8	16.310654	25.647629	0.223897
22	9	16.087204	25.661789	0.223880
22	10	15.863767	25.675858	0.223873
23	1	15.640326	25.689789	0.223865
23	2	15.416888	25.703583	0.223858
23	3	15.193452	25.717316	0.223851
23	4	14.970014	25.730896	0.223846
23	5	14.746573	25.744385	0.223836
23	6	14.523135	25.757721	0.223827
23	7	14.299699	25.770920	0.223821
23	8	14.076261	25.784012	0.223815
23	9	13.852820	25.796982	0.223805
23	10	13.629382	25.809784	0.223797
24	1	13.405946	25.822464	0.223788
24	2	13.182508	25.834961	0.223783
24	3	12.959067	25.847382	0.223771
24	4	12.735631	25.859604	0.223765
24	5	12.512193	25.871689	0.223757
24	6	12.288754	25.883606	0.223747
24	7	12.065314	25.895340	0.223739
24	8	11.841878	25.906952	0.223730
24	9	11.618440	25.918396	0.223724
24	10	11.395000	25.929688	0.223714
25	1	11.171561	25.940796	0.223703
25	2	10.948125	25.951706	0.223696
25	3	10.724687	25.962433	0.223690
25	4	10.501246	25.973038	0.223680
25	5	10.277808	25.983429	0.223670
25	6	10.054372	25.993622	0.223663
25	7	9.830934	26.003647	0.223656
25	8	9.607493	26.013489	0.223647
25	9	9.384055	26.023148	0.223637
25	10	9.160619	26.032593	0.223630
26	1	8.937181	26.041855	0.223622
26	2	8.713740	26.050873	0.223614
26	3	8.490304	26.059769	0.223605
26	4	8.266866	26.068390	0.223599
26	5	8.043427	26.076859	0.223591
26	6	7.819987	26.085114	0.223581
26	7	7.596551	26.093140	0.223575
26	8	7.373113	26.100937	0.223569
26	9	7.149673	26.108582	0.223560
26	10	6.926234	26.115967	0.223553
27	1	6.702798	26.123154	0.223543

27	2	6.479360	26.130112	0.223540
27	3	6.255919	26.136841	0.223534
27	4	6.032481	26.143372	0.223526
27	5	5.809045	26.149643	0.223521
27	6	5.585607	26.155716	0.223516
27	7	5.362166	26.161591	0.223509
27	8	5.138728	26.167206	0.223502
27	9	4.915292	26.172577	0.223498
27	10	4.691854	26.177765	0.223493
28	1	4.468413	26.182663	0.223487
28	2	4.244977	26.187378	0.223483
28	3	4.021539	26.191849	0.223479
28	4	3.798100	26.196091	0.223473
28	5	3.574660	26.200058	0.223469
28	6	3.351224	26.203827	0.223466
28	7	3.127786	26.207352	0.223463
28	8	2.904346	26.210602	0.223459
28	9	2.680907	26.213669	0.223455
28	10	2.457471	26.216446	0.223453
29	1	2.234033	26.219025	0.223451
29	2	2.010592	26.221344	0.223448
29	3	1.787154	26.223404	0.223445
29	4	1.563718	26.225235	0.223444
29	5	1.340280	26.226822	0.223443
29	6	1.116839	26.228180	0.223440
29	7	0.893403	26.229279	0.223439
29	8	0.669966	26.230118	0.223439
29	9	0.446528	26.230713	0.223438
29	10	0.223090	26.231110	0.223090
30	1	0.0	26.231247	0.0
30	2	0.0	0.0	0.0
30	3	0.0	0.0	0.0
30	4	0.0	0.0	0.0
30	5	0.0	0.0	0.0
30	6	0.0	0.0	0.0
30	7	0.0	0.0	0.0
30	8	0.0	0.0	0.0
30	9	0.0	0.0	0.0
30	10	0.0	0.0	0.0

I	MAX. I.	MIN. I.	AREA	VCG	DEPTH
1	10.560399	1.404570	2.547919	4.102559	6.000000
2	17.253708	5.149980	4.553559	4.275189	6.000000
3	21.999649	1.267670	2.935920	5.179449	8.000000
4	32.151489	2.691560	4.428200	5.261410	8.000000
5	47.027786	3.848550	4.322120	6.916630	9.000000
6	64.834717	1.357809	3.913119	7.419299	12.000000
7	246.921356	12.129780	8.529169	10.944189	16.000000
8	393.407471	17.171539	10.781560	12.175449	18.000000
9	1309.426758	91.923447	20.686417	16.908249	24.000000

```
   ST1CRK          ST1CRD          ST2EST          SGMULT          SGMYLD
   7.929999        6.000000        1.339286        20.982132       20.982132
  W5BMIN  =  2.000000   FRM  =  8.000000

  INTERIM TH1  =  0.343750 AND W5BACT  =  2.162113

W5BACT =  2.162113   W5BPRC =  2.162113   W5BTOL =  0.0
  I =  1     J =  1      SUMDST =  0.200056
  I =  1     J =  2      SUMDST =  0.400113
  I =  1     J =  3      SUMDST =  0.600171
  I =  1     J =  4      SUMDST =  0.800231
  I =  1     J =  5      SUMDST =  1.000294
  I =  1     J =  6      SUMDST =  1.200360
  I =  1     J =  7      SUMDST =  1.400431
  I =  1     J =  8      SUMDST =  1.600505
  I =  1     J =  9      SUMDST =  1.800588
  I =  1     J = 10      SUMDST =  2.000679
  I =  2     J =  1      SUMDST =  2.200778

 Y =  2.161354  Z =  0.057184  YPR =  2.000000  ZPR =  0.052099

 CLONGL OUTPUT =    3.096774      10.107035       2.161354        0.057184

W5BACT =  2.162113   W5BPRC =  2.162113   W5BTOL =  0.0

SPAN( 1)  =   2.162113   I =  2  J =  1

W5BACT =  2.162113   W5BPRC =  2.162113   W5BTOL =  2.166965
  I =  2     J =  2      SUMDST =  0.238775
  I =  2     J =  3      SUMDST =  0.438896
  I =  2     J =  4      SUMDST =  0.639034
  I =  2     J =  5      SUMDST =  0.839189
  I =  2     J =  6      SUMDST =  1.039365
  I =  2     J =  7      SUMDST =  1.239564
  I =  2     J =  8      SUMDST =  1.439791
  I =  2     J =  9      SUMDST =  1.640050
  I =  2     J = 10      SUMDST =  1.840349
  I =  3     J =  1      SUMDST =  2.241069

 Y =  4.326030  Z =  0.154977  YPR =  4.000000  ZPR =  0.135401

 CLONGL OUTPUT =    3.096774      10.029918       4.326030        0.154977

W5BACT =  2.162113   W5BPRC =  2.166965   W5BTOL =  2.166965

SPAN( 2)  =   2.166965   I =  3  J =  1

W5BACT =  2.162113   W5BPRC =  2.166965   W5BTOL =  2.175280
  I =  3     J =  2      SUMDST =  0.475011
  I =  3     J =  3      SUMDST =  0.876133
  I =  3     J =  4      SUMDST =  1.277487
  I =  3     J =  5      SUMDST =  1.679098
  I =  3     J =  6      SUMDST =  2.080992
  I =  3     J =  7      SUMDST =  2.483188

 Y =  6.493771  Z =  0.334096  YPR =  6.399998  ZPR =  0.324254

 CLONGL OUTPUT =    3.096774       9.890423       6.493771        0.334096

W5BACT =  2.162113   W5BPRC =  2.175280   W5BTOL =  2.175280

SPAN( 3)  =   2.175280   I =  3  J =  7
```

```
  I =  3     J =  8      SUMDST =  0.710433
  I =  3     J =  9      SUMDST =  1.113308
  I =  3     J = 10      SUMDST =  1.516562
  I =  4     J =  1      SUMDST =  1.920226
  I =  4     J =  2      SUMDST =  2.324408

 Y =  8.667541  Z =  0.603478  YPR =  8.400000  ZPR =  0.564682

 CLONGL OUTPUT =   3.096774      9.684793      8.667541      0.603478

W5BACT =  2.162113   W5BPRC =  2.190565   W5BTOL =  2.190565

SPAN( 4)  =   2.190565   I =  4  J =  2

W5BACT =  2.162113   W5BPRC =  2.190565   W5BTOL =  2.213699
  I =  4     J =  3      SUMDST =  0.538682
  I =  4     J =  4      SUMDST =  0.944335
  I =  4     J =  5      SUMDST =  1.350987
  I =  4     J =  6      SUMDST =  1.758848
  I =  4     J =  7      SUMDST =  2.168156
  I =  4     J =  8      SUMDST =  2.579186

 Y = 10.844317  Z =  1.002817  YPR = 10.799995  ZPR =  0.992337

 CLONGL OUTPUT =   3.096774      9.388797      10.844317     1.002817

W5BACT =  2.162113   W5BPRC =  2.213699   W5BTOL =  2.213699

SPAN( 5)  =   2.213699   I =  4  J =  8

W5BACT =  2.162113   W5BPRC =  2.213699   W5BTOL =  2.248323
  I =  4     J =  9      SUMDST =  0.778546
  I =  4     J = 10      SUMDST =  1.193976
  I =  5     J =  1      SUMDST =  1.397257
  I =  5     J =  2      SUMDST =  1.601236
  I =  5     J =  3      SUMDST =  1.805963
  I =  5     J =  4      SUMDST =  2.011485
  I =  5     J =  5      SUMDST =  2.217855
  I =  5     J =  6      SUMDST =  2.425129

 Y = 13.002581  Z =  1.627934  YPR = 12.973948  ZPR =  1.617520

 CLONGL OUTPUT =   3.096774      8.945485      13.002581     1.627934

W5BACT =  2.162113   W5BPRC =  2.248323   W5BTOL =  2.248323

SPAN( 6)  =   2.248323   I =  5  J =  6

W5BACT =  2.162113   W5BPRC =  2.248323   W5BTOL =  2.303361
  I =  5     J =  7      SUMDST =  0.385037
  I =  5     J =  8      SUMDST =  0.594287
  I =  5     J =  9      SUMDST =  0.804614
  I =  5     J = 10      SUMDST =  1.015530
  I =  6     J =  1      SUMDST =  1.239614
  I =  6     J =  2      SUMDST =  1.465177
  I =  6     J =  3      SUMDST =  1.692369
  I =  6     J =  4      SUMDST =  1.921377
  I =  6     J =  5      SUMDST =  2.152349
  I =  6     J =  6      SUMDST =  2.385499

 Y = 15.106862  Z =  2.559123  YPR = 14.973948  ZPR =  2.487440

 CLONGL OUTPUT =   3.096774      8.326877      15.106862     2.559123

W5BACT =  2.162113   W5BPRC =  2.303361   W5BTOL =  2.303361
```

```
SPAN( 7)  =   2.303361   I = 6   J =  6
```



```
W5BACT =   2.162113    W5BPRC =   2.303361    W5BTOL =   2.387387
  I =  6      J =  7        SUMDST =  0.317640
  I =  6      J =  8        SUMDST =  0.555713
  I =  6      J =  9        SUMDST =  0.796553
  I =  6      J = 10        SUMDST =  1.047133
  I =  7      J =  1        SUMDST =  1.188572
  I =  7      J =  2        SUMDST =  1.331222
  I =  7      J =  3        SUMDST =  1.475191
  I =  7      J =  4        SUMDST =  1.620585
  I =  7      J =  5        SUMDST =  1.767613
  I =  7      J =  6        SUMDST =  1.916717
  I =  7      J =  7        SUMDST =  2.067707
  I =  7      J =  8        SUMDST =  2.220990
  I =  7      J =  9        SUMDST =  2.376628
  I =  7      J = 10        SUMDST =  2.527033

 Y = 17.067734  Z =  3.912447  YPR = 17.059357  ZPR =  3.905701

W5BACT =  2.162113   W5BPRC =  2.387387   W5BTOL =  2.387387

 CLONGL OUTPUT =   3.096774        7.506919      17.067734        3.912447

W5BACT =  2.162113   W5BPRC =  2.387387   W5BTOL =  2.387387

SPAN( 8)  =   2.387387   I =  7  J = 10

W5BACT =   2.162113    W5BPRC =   2.387387    W5BTOL =   2.514391
  I =  8      J =  1        SUMDST =  0.432994
  I =  8      J =  2        SUMDST =  0.720609
  I =  8      J =  3        SUMDST =  1.002813
  I =  8      J =  4        SUMDST =  1.279888
  I =  8      J =  5        SUMDST =  1.552101
  I =  8      J =  6        SUMDST =  1.819724
  I =  8      J =  7        SUMDST =  2.083023
  I =  8      J =  8        SUMDST =  2.342276
  I =  8      J =  9        SUMDST =  2.597717

 Y = 18.794434  Z =  5.734756  YPR = 18.687378  ZPR =  5.599998

 CLONGL OUTPUT =   3.096774        6.528984      18.794434        5.734756

W5BACT =  2.162113   W5BPRC =  2.514391   W5BTOL =  2.514391

SPAN( 9)  =   2.514391   I =  8  J =  9

W5BACT =   2.162113    W5BPRC =   2.514391    W5BTOL =   2.696131
  I =  8      J = 10        SUMDST =  0.335511
  I =  9      J =  1        SUMDST =  0.529975
  I =  9      J =  2        SUMDST =  0.722415
  I =  9      J =  3        SUMDST =  0.912863
  I =  9      J =  4        SUMDST =  1.101335
  I =  9      J =  5        SUMDST =  1.287874
  I =  9      J =  6        SUMDST =  1.472521
  I =  9      J =  7        SUMDST =  1.655266
  I =  9      J =  8        SUMDST =  1.836177
  I =  9      J =  9        SUMDST =  2.015270
  I =  9      J = 10        SUMDST =  2.191730
  I = 10      J =  1        SUMDST =  2.241062
  I = 10      J =  2        SUMDST =  2.290276
  I = 10      J =  3        SUMDST =  2.339369
  I = 10      J =  4        SUMDST =  2.388368
  I = 10      J =  5        SUMDST =  2.437263
  I = 10      J =  6        SUMDST =  2.486099
```

```
  I = 10     J =  8       SUMDST =  2.583558
  I = 10     J =  9       SUMDST =  2.632205
  I = 10     J = 10       SUMDST =  2.681940
  I = 11     J =  1       SUMDST =  2.903823

 Y = 20.225235  Z =  8.012792  YPR = 20.219101  ZPR =  8.000000

 CLONGL OUTPUT =   3.096774        5.473187       20.225235        8.012792

W5BACT =  2.162113   W5BPRC =  2.696131   W5BTOL =  2.696131

SPAN(10)   =   2.696131   I = 11  J =  1

W5BACT =  2.162113   W5BPRC =  2.696131   W5BTOL =  2.944719
  I = 11     J =  2       SUMDST =  0.428886
  I = 11     J =  3       SUMDST =  0.649316
  I = 11     J =  4       SUMDST =  0.868908
  I = 11     J =  5       SUMDST =  1.087596
  I = 11     J =  6       SUMDST =  1.305339
  I = 11     J =  7       SUMDST =  1.522044
  I = 11     J =  8       SUMDST =  1.737678
  I = 11     J =  9       SUMDST =  1.952217
  I = 11     J = 10       SUMDST =  2.165445
  I = 12     J =  1       SUMDST =  2.377673
  I = 12     J =  2       SUMDST =  2.588840
  I = 12     J =  3       SUMDST =  2.799034
  I = 12     J =  4       SUMDST =  3.008346

 Y = 21.329575  Z = 10.739202  YPR = 21.286606  ZPR = 10.599998

 CLONGL OUTPUT =   3.096774        4.402401       21.329575       10.739202

W5BACT =  2.162113   W5BPRC =  2.944719   W5BTOL =  2.944719

SPAN(11)   =   2.944719   I = 12  J =  4

W5BACT =  2.162113   W5BPRC =  2.944719   W5BTOL =  3.283364
  I = 12     J =  5       SUMDST =  0.272135
  I = 12     J =  6       SUMDST =  0.479927
  I = 12     J =  7       SUMDST =  0.687077
  I = 12     J =  8       SUMDST =  0.893653
  I = 12     J =  9       SUMDST =  1.099717
  I = 12     J = 10       SUMDST =  1.305297
  I = 13     J =  1       SUMDST =  1.561737
  I = 13     J =  2       SUMDST =  1.817595
  I = 13     J =  3       SUMDST =  2.072915
  I = 13     J =  4       SUMDST =  2.327721
  I = 13     J =  5       SUMDST =  2.582062
  I = 13     J =  6       SUMDST =  2.835966
  I = 13     J =  7       SUMDST =  3.089468
  I = 13     J =  8       SUMDST =  3.342599

 Y = 22.042709  Z = 13.941499  YPR = 22.012314  ZPR = 13.750000

 CLONGL OUTPUT =   3.096774        3.351851       22.042709       13.941499

W5BACT =  2.162113   W5BPRC =  3.283364   W5BTOL =  3.283364

SPAN(12)   =   3.283364   I = 13  J =  8

W5BACT =  2.162113   W5BPRC =  3.283364   W5BTOL =  3.762891
  I = 13     J =  9       SUMDST =  0.312026
  I = 13     J = 10       SUMDST =  0.564520
  I = 14     J =  1       SUMDST =  0.715868
  I = 14     J =  2       SUMDST =  0.867115
```

```
  I = 14     J =  4     SUMDST =  1.169319
  I = 14     J =  5     SUMDST =  1.320289
  I = 14     J =  6     SUMDST =  1.471170
  I = 14     J =  7     SUMDST =  1.621969
  I = 14     J =  8     SUMDST =  1.772695
  I = 14     J =  9     SUMDST =  1.923343
  I = 14     J = 10     SUMDST =  2.073926
  I = 15     J =  1     SUMDST =  2.274590
  I = 15     J =  2     SUMDST =  2.475154
  I = 15     J =  3     SUMDST =  2.675629
  I = 15     J =  4     SUMDST =  2.876027
  I = 15     J =  5     SUMDST =  3.076361
  I = 15     J =  6     SUMDST =  3.276639
  I = 15     J =  7     SUMDST =  3.476873
  I = 15     J =  8     SUMDST =  3.677068
  I = 15     J =  9     SUMDST =  3.877233

 Y = 22.394119  Z = 17.685715  YPR = 22.390610  ZPR = 17.599976

 CLONGL OUTPUT =    3.096774        2.714253        22.394119       17.685715

W5BACT =   2.162113   W5BPRC =  3.762891   W5BTOL =  3.762891

SPAN(13)   =    3.762891    I = 15   J =  9

W5BACT =   2.162113   W5BPRC =  3.762891   W5BTOL =  4.181564
  I = 15     J = 10     SUMDST =  0.314507
  I = 16     J =  1     SUMDST =  0.514625
  I = 16     J =  2     SUMDST =  0.714724
  I = 16     J =  3     SUMDST =  0.914804
  I = 16     J =  4     SUMDST =  1.114867
  I = 16     J =  5     SUMDST =  1.314916
  I = 16     J =  6     SUMDST =  1.514950
  I = 16     J =  7     SUMDST =  1.714972
  I = 16     J =  8     SUMDST =  1.914985
  I = 16     J =  9     SUMDST =  2.114990
  I = 16     J = 10     SUMDST =  2.315019
  I = 17     J =  1     SUMDST =  2.515017
  I = 17     J =  2     SUMDST =  2.715014
  I = 17     J =  3     SUMDST =  2.915012
  I = 17     J =  4     SUMDST =  3.115014
  I = 17     J =  5     SUMDST =  3.315020
  I = 17     J =  6     SUMDST =  3.515031
  I = 17     J =  7     SUMDST =  3.715050
  I = 17     J =  8     SUMDST =  3.915074
  I = 17     J =  9     SUMDST =  4.115107
  I = 17     J = 10     SUMDST =  4.315178

 Y = 22.429413  Z = 21.866409  YPR = 22.430832  ZPR = 21.799973

W5BACT =   2.162113   W5BPRC =  4.181564   W5BTOL =  4.181564

 CLONGL OUTPUT =    3.096774        2.061488        22.429413       21.866409

W5BACT =   2.162113   W5BPRC =  4.181564   W5BTOL =  4.181564

SPAN(14)   =    4.181564    I = 17   J = 10

W5BACT =   2.162113   W5BPRC =  4.181564   W5BTOL =   3.582268
  I = 18     J =  1     SUMDST =  0.333661
  I = 18     J =  2     SUMDST =  0.533715
  I = 18     J =  3     SUMDST =  0.733774
  I = 18     J =  4     SUMDST =  0.933838
  I = 18     J =  5     SUMDST =  1.133906
  I = 18     J =  6     SUMDST =  1.333976
```

```
 I = 18      J =  8       SUMDST =  1.734119
 I = 18      J =  9       SUMDST =  1.934190
 I = 18      J = 10       SUMDST =  2.134281
 I = 19      J =  1       SUMDST =  2.258256
 I = 19      J =  2       SUMDST =  2.382244
 I = 19      J =  3       SUMDST =  2.506231
 I = 19      J =  4       SUMDST =  2.630234
 I = 19      J =  5       SUMDST =  2.754219
 I = 19      J =  6       SUMDST =  2.878203
 I = 19      J =  7       SUMDST =  3.002172
 I = 19      J =  8       SUMDST =  3.126157
 I = 19      J =  9       SUMDST =  3.250141
 I = 19      J = 10       SUMDST =  3.374258

SPAN(15)  =    3.374258    I = 19   J = 10

 Y = 22.343796   Z = 25.239594   YPR = 22.343796  ZPR = 25.239594
 I = 20      J =  1       SUMDST =  0.224005
 I = 20      J =  2       SUMDST =  0.447998
 I = 20      J =  3       SUMDST =  0.671974
 I = 20      J =  4       SUMDST =  0.895963
 I = 20      J =  5       SUMDST =  1.119967
 I = 20      J =  6       SUMDST =  1.343939
 I = 20      J =  7       SUMDST =  1.567926
 I = 20      J =  8       SUMDST =  1.791924
 I = 20      J =  9       SUMDST =  2.015907
 I = 20      J = 10       SUMDST =  2.239871
 I = 21      J =  1       SUMDST =  2.463848
 I = 21      J =  2       SUMDST =  2.687837
 I = 21      J =  3       SUMDST =  2.911792
 I = 21      J =  4       SUMDST =  3.135758
 I = 21      J =  5       SUMDST =  3.359739
 I = 21      J =  6       SUMDST =  3.583699

 Y = 18.769989   Z = 25.486084   YPR = 18.992035   ZPR = 25.471065

 CLONGL OUTPUT =    3.096774        1.329552        18.769989        25.486084

W5BACT =   2.162113    W5BPRC =   3.582268    W5BTOL =   3.582268

SPAN(16)  =    3.582268    I = 21   J =  6

W5BACT =   2.162113    W5BPRC =   3.582268    W5BTOL =   3.019865
 I = 21      J =  7       SUMDST =  0.225371
 I = 21      J =  8       SUMDST =  0.449340
 I = 21      J =  9       SUMDST =  0.673287
 I = 21      J = 10       SUMDST =  0.897214
 I = 22      J =  1       SUMDST =  1.121151
 I = 22      J =  2       SUMDST =  1.345098
 I = 22      J =  3       SUMDST =  1.569009
 I = 22      J =  4       SUMDST =  1.792931
 I = 22      J =  5       SUMDST =  2.016862
 I = 22      J =  6       SUMDST =  2.240771
 I = 22      J =  7       SUMDST =  2.464658
 I = 22      J =  8       SUMDST =  2.688555
 I = 22      J =  9       SUMDST =  2.912435
 I = 22      J = 10       SUMDST =  3.136307

 Y = 15.756542   Z = 25.682541   YPR = 15.863767   ZPR = 25.675858

W5BACT =   2.162113    W5BPRC =   3.019865    W5BTOL =   3.019865

 CLONGL OUTPUT =    3.096774        1.284049        15.756542        25.682541

W5BACT =   2.162113    W5BPRC =   3.019865    W5BTOL =   3.019865
```

SPAN(17) = 3.019865 I = 22 J = 10


```
W5BACT =  2.162113   W5BPRC =  3.019865   W5BTOL =  2.962949
  I = 23     J =  1      SUMDST =  0.340307
  I = 23     J =  2      SUMDST =  0.564165
  I = 23     J =  3      SUMDST =  0.788016
  I = 23     J =  4      SUMDST =  1.011861
  I = 23     J =  5      SUMDST =  1.235697
  I = 23     J =  6      SUMDST =  1.459523
  I = 23     J =  7      SUMDST =  1.683344
  I = 23     J =  8      SUMDST =  1.907159
  I = 23     J =  9      SUMDST =  2.130963
  I = 23     J = 10      SUMDST =  2.354760
  I = 24     J =  1      SUMDST =  2.578547
  I = 24     J =  2      SUMDST =  2.802330
  I = 24     J =  3      SUMDST =  3.026100

 Y = 12.798687  Z = 25.856140  YPR = 12.959067  ZPR = 25.847382

 CLONGL OUTPUT =   3.096774      1.243269      12.798687      25.856140

W5BACT =  2.162113   W5BPRC =  2.962949   W5BTOL =  2.962949

SPAN(18)  =   2.962949   I = 24  J =  3

W5BACT =  2.162113   W5BPRC =  2.962949   W5BTOL =  2.939541
  I = 24     J =  4      SUMDST =  0.286916
  I = 24     J =  5      SUMDST =  0.510673
  I = 24     J =  6      SUMDST =  0.734420
  I = 24     J =  7      SUMDST =  0.958159
  I = 24     J =  8      SUMDST =  1.181889
  I = 24     J =  9      SUMDST =  1.405612
  I = 24     J = 10      SUMDST =  1.629326
  I = 25     J =  1      SUMDST =  1.853028
  I = 25     J =  2      SUMDST =  2.076724
  I = 25     J =  3      SUMDST =  2.300413
  I = 25     J =  4      SUMDST =  2.524093
  I = 25     J =  5      SUMDST =  2.747762
  I = 25     J =  6      SUMDST =  2.971424

 Y =  9.862784  Z = 26.002213  YPR = 10.054372  ZPR = 25.993622

 CLONGL OUTPUT =   3.096774      1.208532       9.862784      26.002213

W5BACT =  2.162113   W5BPRC =  2.939541   W5BTOL =  2.939541

SPAN(19)  =   2.939541   I = 25  J =  6

W5BACT =  2.162113   W5BPRC =  2.939541   W5BTOL =  2.921926
  I = 25     J =  7      SUMDST =  0.255539
  I = 25     J =  8      SUMDST =  0.479186
  I = 25     J =  9      SUMDST =  0.702823
  I = 25     J = 10      SUMDST =  0.926453
  I = 26     J =  1      SUMDST =  1.150075
  I = 26     J =  2      SUMDST =  1.373689
  I = 26     J =  3      SUMDST =  1.597293
  I = 26     J =  4      SUMDST =  1.820891
  I = 26     J =  5      SUMDST =  2.044482
  I = 26     J =  6      SUMDST =  2.268063
  I = 26     J =  7      SUMDST =  2.491637
  I = 26     J =  8      SUMDST =  2.715206
  I = 26     J =  9      SUMDST =  2.938766

 Y =  6.943064  Z = 26.115402  YPR =  7.149673  ZPR = 26.108582
```

```
W5BACT =   2.162113   W5BPRC =   2.921926   W5BTOL =   2.921926

SPAN(20)  =    2.921926   I = 26   J =  9

W5BACT =   2.162113   W5BPRC =   2.921926   W5BTOL =   2.908485
  I = 26     J = 10      SUMDST =  0.240392
  I = 27     J =  1      SUMDST =  0.463939
  I = 27     J =  2      SUMDST =  0.687479
  I = 27     J =  3      SUMDST =  0.911013
  I = 27     J =  4      SUMDST =  1.134539
  I = 27     J =  5      SUMDST =  1.358059
  I = 27     J =  6      SUMDST =  1.581574
  I = 27     J =  7      SUMDST =  1.805083
  I = 27     J =  8      SUMDST =  2.028584
  I = 27     J =  9      SUMDST =  2.252082
  I = 27     J = 10      SUMDST =  2.475574
  I = 28     J =  1      SUMDST =  2.699061
  I = 28     J =  2      SUMDST =  2.922544

 Y =  4.035593  Z = 26.191559  YPR =  4.244977  ZPR = 26.187378

 CLONGL OUTPUT =   3.096774       1.162918       4.035593      26.191559

W5BACT =   2.162113   W5BPRC =   2.908485   W5BTOL =   2.908485

SPAN(21)  =    2.908485   I = 28   J =  2

W5BACT =   2.162113   W5BPRC =   2.908485   W5BTOL =   2.899400
  I = 28     J =  3      SUMDST =  0.237537
  I = 28     J =  4      SUMDST =  0.461010
  I = 28     J =  5      SUMDST =  0.684479
  I = 28     J =  6      SUMDST =  0.907945
  I = 28     J =  7      SUMDST =  1.131408
  I = 28     J =  8      SUMDST =  1.354866
  I = 28     J =  9      SUMDST =  1.578321
  I = 28     J = 10      SUMDST =  1.801773
  I = 29     J =  1      SUMDST =  2.025224
  I = 29     J =  2      SUMDST =  2.248672
  I = 29     J =  3      SUMDST =  2.472116
  I = 29     J =  4      SUMDST =  2.695560
  I = 29     J =  5      SUMDST =  2.919003

 Y =  1.136441  Z = 26.228058  YPR =  1.340280  ZPR = 26.226822

 CLONGL OUTPUT =   3.096774       1.154048       1.136441      26.228058

W5BACT =   2.162113   W5BPRC =   2.899400   W5BTOL =   2.899400

SPAN(22)  =    2.899400   I = 29   J =  5

W5BACT =   2.162113   W5BPRC =   2.899400   W5BTOL =   2.894860
  I = 29     J =  6      SUMDST =  0.243043
  I = 29     J =  7      SUMDST =  0.466482
  I = 29     J =  8      SUMDST =  0.689921
  I = 29     J =  9      SUMDST =  0.913359
  I = 29     J = 10      SUMDST =  1.136448
  I = 30     J =  1      SUMDST =  1.136448
```

I	Y	Z	YPR	ZPR	SPAN(I)
2	4.326030	0.154977	4.000000	0.135401	2.166965
3	6.493771	0.334096	6.399998	0.324254	2.175280
4	8.667541	0.603478	8.400000	0.594682	2.190565
5	10.844317	1.002817	10.799995	0.992337	2.213699
6	13.002581	1.627934	12.973948	1.617520	2.248325
7	15.106862	2.559123	14.973948	2.487440	2.303361
8	17.067734	3.912447	17.059357	3.905701	2.387387
9	18.794434	5.734756	18.687378	5.599998	2.514391
10	20.225235	8.012792	20.219101	8.000000	2.696131
11	21.329575	10.739202	21.286606	10.599998	2.944719
12	22.042709	13.941499	22.012314	13.750000	3.283364
13	22.394119	17.685715	22.390610	17.599976	3.762891
14	22.429413	21.866409	22.430832	21.799973	4.181564
15	22.343796	25.239594	22.343796	25.239594	3.374258
16	18.769989	25.486084	13.992035	25.471085	3.582268
17	15.756542	25.682541	15.863767	25.675858	3.019865
18	12.798687	25.856140	12.959067	25.847382	2.962949
19	9.862784	26.002213	10.054372	25.993622	2.939541
20	6.943064	26.115402	7.149673	26.108582	2.921926
21	4.035593	26.191559	4.244977	26.187378	2.908485
22	1.136441	26.228058	1.340280	26.226822	2.899400
23	0.0	0.0	0.0	0.0	1.136448
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0

CGCG(1) = 1.459806

LONGITUDINAL (1) IS SELECTED

CGCG(1) = 2.107491

LONGITUDINAL (2) IS SELECTED

CGCG(1) = 1.948315

LONGITUDINAL (3) IS SELECTED

CGCG(1) = 2.499537

LONGITUDINAL (4) IS SELECTED

CGCG(1) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(2) = 3.166634

```
CGCG( 3)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 4)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 5)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 6)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 7)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 8)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 9)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(10)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(11)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(12)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(13)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(14)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(15)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(16)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(17)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(18)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
```

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LONGITUDINAL ( 5)  IS SELECTED
CGCG(20)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(21)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(22)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
I =   1    HM =  30.174057
LONGITUDINAL ( 5)  IS SELECTED
I =   2    HM =  30.076263
LONGITUDINAL ( 5)  IS SELECTED
I =   3    HM =  29.897141
LONGITUDINAL ( 5)  IS SELECTED
I =   4    HM =  29.627762
LONGITUDINAL ( 5)  IS SELECTED
I =   5    HM =  29.228424
LONGITUDINAL ( 5)  IS SELECTED
I =   6    HM =  28.603302
LONGITUDINAL ( 5)  IS SELECTED
I =   7    HM =  27.672119
LONGITUDINAL ( 5)  IS SELECTED
I =   8    HM =  26.318787
LONGITUDINAL ( 5)  IS SELECTED
I =   9    HM =  24.496490
LONGITUDINAL ( 5)  IS SELECTED
I =  10    HM =  22.218445
LONGITUDINAL ( 5)  IS SELECTED
I =  11    HM =  19.492035
LONGITUDINAL ( 5)  IS SELECTED
I =  12    HM =  16.289734
LONGITUDINAL ( 5)  IS SELECTED
I =  13    HM =  12.545532
```

```
I =  14     HM =    8.364838
LONGITUDINAL ( 5)  IS SELECTED
I =  15     HM =    4.991653
LONGITUDINAL ( 5)  IS SELECTED
I =  16     HM =    4.745163
LONGITUDINAL ( 5)  IS SELECTED
I =  17     HM =    4.548706
LONGITUDINAL ( 5)  IS SELECTED
I =  18     HM =    4.375107
LONGITUDINAL ( 5)  IS SELECTED
I =  19     HM =    4.229034
LONGITUDINAL ( 5)  IS SELECTED
I =  20     HM =    4.115845
LONGITUDINAL ( 5)  IS SELECTED
I =  21     HM =    4.039688
LONGITUDINAL ( 5)  IS SELECTED
I =  22     HM =    4.003189
LONGITUDINAL ( 5)  IS SELECTED
XMINER( 1) =      160.853806
XMINER( 2) =      160.853806
XMINER( 3) =      160.853806
XMINER( 4) =      160.853806
XMINER( 5) =      160.853806
XMINER( 6) =      160.853806
XMINER( 7) =      160.853806
XMINER( 8) =      160.853806
XMINER( 9) =      160.853806
XMINER(10) =      160.853806
XMINER(11) =      160.853806
XMINER(12) =      160.853806
XMINER(13) =      160.853806
XMINER(14) =      160.853806
```

```
XMINER(16) =      160.853806
XMINER(17) =      160.853806
XMINER(18) =      160.853806
XMINER(19) =      160.353806
XMINER(20) =      160.853806
XMINER(21) =      160.853806
XMINER(22) =      160.853806
LONGITUDINAL ( 5)  IS SELECTED
BASEMT( 1)  =   1.465505
BASEMT( 2)  =   0.730327
BASEMT( 3)  =   0.907333
BASEMT( 4)  =   1.173897
BASEMT( 5)  =   1.563735
BASEMT( 6)  =   2.169605
BASEMT( 7)  =   3.066433
BASEMT( 8)  =   4.361360
BASEMT( 9)  =   6.093286
BASEMT(10)  =   8.262015
BASEMT(11)  =  10.909203
BASEMT(12)  =  14.031854
BASEMT(13)  =  17.709274
BASEMT(14)  =  21.854095
BASEMT(15)  =   0.0
BASEMT(16)  =  24.910995
BASEMT(17)  =  25.107269
BASEMT(18)  =  25.280609
BASEMT(19)  =  25.426392
BASEMT(20)  =  25.539322
BASEMT(21)  =  25.615280
BASEMT(22)  =  25.651672
```

```
SPAN( 1)  =  2.162113
SPAN( 2)  =  2.166965
SPAN( 3)  =  2.175280
SPAN( 4)  =  2.190565
SPAN( 5)  =  2.213699
SPAN( 6)  =  2.248323
SPAN( 7)  =  2.303361
SPAN( 8)  =  2.387387
SPAN( 9)  =  2.514391
SPAN(10)  =  2.696131
SPAN(11)  =  2.944719
SPAN(12)  =  3.283364
SPAN(13)  =  3.762891
SPAN(14)  =  4.181564
SPAN(15)  =  3.374258
SPAN(16)  =  3.582268
SPAN(17)  =  3.019865
SPAN(18)  =  2.962949
SPAN(19)  =  2.939541
SPAN(20)  =  2.921926
SPAN(21)  =  2.908485
SPAN(22)  =  2.899400
SPAN(23)  =  1.136448
SPAN(24)  =  0.0
SPAN(25)  =  0.0
SPAN(26)  =  0.0
SPAN(27)  =  0.0
SPAN(28)  =  0.0
SPAN(29)  =  0.0
SPAN(30)  =  0.0
SPAN(31)  =  0.0
SPAN(32)  =  0.0
```

```
SPAN(33)   =   0.0
SPAN(34)   =   0.0
SPAN(35)   =   0.0
SPAN(36)   =   0.0
SPAN(37)   =   0.0
SPAN(38)   =   0.0
SPAN(39)   =   0.0
SPAN(40)   =   0.0
```

I	Y	Z	YPR	ZPR	SPAN(I)
1	2.161354	0.057184	2.000000	0.052099	2.162113
2	4.326030	0.154977	4.000000	0.135401	2.166965
3	6.493771	0.334096	6.399998	0.324254	2.175280
4	8.667541	0.603478	8.400000	0.564682	2.190565
5	10.844317	1.002817	10.799995	0.992337	2.213699
6	13.002581	1.627934	12.973948	1.617520	2.248323
7	15.106862	2.559123	14.973948	2.487440	2.303361
8	17.067734	3.912447	17.059357	3.905701	2.387387
9	18.794434	5.734756	18.687376	5.599998	2.514391
10	20.225235	8.012792	20.219101	8.000000	2.696131
11	21.329575	10.739202	21.286606	10.599998	2.944719
12	22.042709	13.941499	22.012314	13.750000	3.283364
13	22.394119	17.685715	22.390610	17.599976	3.762891
14	22.429413	21.866409	22.430832	21.799973	4.181564
15	22.343796	25.239594	22.343796	25.239594	3.374258
16	18.769989	25.486084	18.992035	25.471085	3.582268
17	15.756542	25.682541	15.863767	25.675858	3.019865
18	12.798687	25.856140	12.959067	25.847382	2.962949
19	9.862784	26.002213	10.054372	25.993622	2.939541
20	6.943064	26.115402	7.149673	26.108582	2.921926
21	4.035593	26.191559	4.244977	26.187378	2.908485
22	1.136441	26.228058	1.340280	26.226822	2.899400
23	0.0	0.0	0.0	0.0	1.136448
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0

```
REQUIRED MOMENT OF INERTIA =         139535.875000 IN**2  FT**2

ACTUAL MOMENT OF INERTIA =           79760.437500 IN**2  FT**2

MAX. TOLERABLE ST1CRK = 7.9299994 TONS PER SQ. INCH

ACTUAL ST1CRK =12.9492407 TONS PER SQ. INCH

MAX. TOLERABLE ST1CRD = 6.0000000TONS PER SQ. INCH

ACTUAL ST1CRD = 8.3842268 TONS PER SQ. INCH

TOTAL WEIGHT = 1.2419310 TONS PER FOOT LENGTH

TOTAL WEIGHT =   2781.9257812 POUNDS PER FOOT LENGTH

    PLATING WEIGHT =   1766.4226074 POUNDS PER FOOT LENGTH
    LONGITUDINAL WEIGHT =    658.1281738 POUNDS PER FOOT LENGTH
    TRANSVERSE FRAME WEIGHT =    357.3750000 POUNDS PER FOOT LENGTH

NEUTRAL AXIS IS 13.9384232 FEET ABOVE BASE LINE

SCANTLING   5  SELECTED--CROSS-SECTION AREA IS 4.3221197  SQ. IN. AND WEB DEPTH IS  9.0000000 INCHES.

KEEL HAS AN AREA OF20.6864166 SQ. IN. AND A WEB DEPTH OF 24.0000000 INCHES.

  SELECTED PLATING THICKNESS =   0.343750 INCHES.

    DESIGN REPEATED WITH TH1 INCREASED
```

B. MAIN PROGRAM COSTDATA

1. DESCRIPTION

Introduction

Main program COSDATA carries out the cost calculation for the midship section of DD-931, using as inputs much of the design information generated by program RUNSCORE. Materials cost data, extracted from [3], are combined with various handling and erection costs to generate a total cost, per foot length of midship section, for the construction of DD-931 primary hull structure.

For reference purposes, the acquisition cost data for HTS structural members are listed in Table IV on the following pages. These members, when procured through the Federal supply system, are not discounted in price for quantity acquisitions.

The methods used by the cost estimators of the Boston Naval Shipyard were employed in main program COSDATA. All these charges are based on the cost of one man-hour of work, including yard overhead. For the purposes of this investigation, one man-hour has been arbitrarily assumed to cost $ 7.50.

Main program COSTDATA takes the series of intervals

TABLE IV

AVAILABLE PLATES AND SHAPES -
DESCRIPTION AND ACQUISITION COSTS

Plates

Thickness (Inches)	Width (Ft.)	Length (Ft.)	Cost Total	Cost Sq. Ft.
0.25	8	20	$ 169	$ 1.058
	8	29	274	1.181
	5	20	128	1.28
0.28125	8	29	305	1.316
0.3125	6	29	238	1.37
	8	29	353	1.522
0.34375	8	29	383	1.651
0.375	8	20	254	1.587
	5	20	161	1.61
	6	29	281	1.618
	8	29	383	1.652
0.4375	6	29	394	2.264
0.50	8	33	569	2.158
	5	20	237	2.37
	8	29	551	2.375
	8	20	394	2.462
	6	29	483	2.796
0.625	8	33	818	2.984
	5	20	306	3.06
	6	29	532	3.06
0.75	8	33	959	3.635
	8	20	614	3.84
0.875	8	16	500	3.905
	6	20	498	4.15
	8	29	1030	4.44
	15	25.16	1958	5.19
0.9375	8	20	720	4.50
1.00	8	20	725	4.53
	5	20	481	4.81
	8	29	1233	5.32

TABLE IV - Continued

Shapes*

No.	Depth (In.)	Flg. Width (In.)	Weight (Lb./Ft.)	Cost Per Ft.
1	6	4	12.0	$ 2.00
2	6	6.063	22.6	2.40
3	8	4	13.0	1.40
4	8	5.36	20.00	2.40
5	9.9	5.75	21.0	2.70
6	12	4	16.5	2.30
7	16	7	40.0	3.90
8	18	7.5	50.0	5.50
9	24	12	100.0	9.00

*All shapes have a length of 40 feet.

between longitudinals for half the midship section and generates a set of intervals for the entire section. This is designed to facilitate the later calculation of butt locations to insure a clearance of at least four inches between any given butt joint and a longitudinal-plating intersection.

The cost of welding any of the various possible size plates is calculated, using the input value of cost of butt welding the given thickness of shell plating (man-hours per foot length of weld).

Plating Thickness (Inches)	Cost of Butt Weld[4]* (Man-Hours per Foot)
0.25	0.38
0.28125	0.43
0.3125	0.48
0.34375	0.53
0.375	0.58
0.4375	0.68
0.50	0.76
0.625	1.22
0.75	1.60
0.875	2.02
0.9375	2.22
1.00	2.42

The program next calculates the number of plates required to go around the girth of the midship section. The alternate plate sizes of the appropriate thickness must be arranged in ascending order of cost per square foot area. The first plate is centered over the keel, and successive plates are added in progression around the girth of the midship section. Should a conflict arise in that a butt

---

*This information is for work on board ship under <u>difficult</u> conditions. Other conditions are <u>normal</u> and <u>complex</u>.

joint is too near to a longitudinal-plating intersection, the algorithm first attempts to select the next available plating size. If this proves to be impossible, then a cut of 0.7 feet is made from the end of the plate. The following charges are made for cutting plates:

Plating Thickness (Inches)	Cost of Cut* (Man-Hours per Foot)	Type Cut
0.25	0.05	Flame cut
0.375	0.06	Flame cut
0.50	0.07	Flame cut
0.625	0.08	Flame cut
0.75	0.09	Flame cut
0.875	0.10	Flame cut
1.00	0.11	Flame cut

The net cost of butt welding the plates is next calculated, given the total number of plates of each individual size employed in the midship section structure. The cost of any plate cuts is calculated, using the previously listed cost data per cut per foot plate length.

The cost of rolling the plates, using average man-hour charges allocated by the Boston Naval Shipyard, based on a plate length of twenty feet, is computed next. The standard charges for such plates (twenty feet long) are as follows:

Plating Thickness (Inches)	Cost of Rolling (Man-Hours per Plate)
0.25	2.9
0.50	2.9
0.75	3.9
1.00	3.9

---

*Information provided by Mr. Joseph Palange, a Planner and Estimator with the Boston Naval Shipyard.

Typical rigging costs are evaluated, using an arbitrarily specified "mix" of staging comprising two platforms twenty feet high, two fourteen feet high, two eight feet high, and two three feet high. Again, normal Boston Naval Shipyard charges based on staging five feet long are evaluated on the basis of the per-foot length costs.

The acquisition cost of the plating is computed, using the input data provided the program and the determined number of plates employed of each given size.

The expense involved in the procurement, cutting, and welding of longitudinal wide flange sections is next calculated. The previously defined cost criteria for plate cutting are used for evaluating the expenses involved in cutting the shape flanges. Next, the cost of welding the longitudinals is evaluated, using normal Boston Naval Shipyard charges similar to those described in terms of the cost of butt welds:

Longitudinal Number	Welding Cost (Man-Hours per Foot)
1	0.34
2	0.50
3	0.34
4	0.42
5	0.42
6	0.34
7	0.66
8	1.04

Additionally, for all welding operations, certain fixed charges are added. These allow for making ready

and putting away equipment, wire brushing, arc air, dye penetrant for weld inspection, and strip heaters for heat treating welds.

An approximate evaluation of the cost contribution of the transverse frame structure is made, estimating that the cost of the transverse frame, on the average, is seventy per cent that of the centerline vertical keel, per foot length.

Once all these individual costs are calculated, the total cost of the midship section structure, per foot length, is determined.

Inputs

Symbol	Meaning
CWLDMH	Cost of butt weld. (Man-Hours per foot length)
THL	Plating thickness. (Inches)
XLGTNL	The number of longitudinals in the midship section.
CHGMNH	The cost of one man-hour of work. (Dollars)
COSTKL	The total cost of the keel structure. (Dollars per foot length)
TOTSPN	The total midship section girth. (Feet)
CROLL	The cost of rolling a plate twenty feet long. (Dollars)
CSTLGL	The acquisition cost of a longitudinal. (Dollars per foot length)
SPAN(I)	The interval to longitudinal (I). (Feet)
CWLGTL	The cost of welding a longitudinal. (Man-Hours per foot length)

Symbol	Meaning
PLT(I,1)	Width of plate(I). (Feet)
PLT(I,2)	Length of plate(I). (Feet)
PLT(I,3)	Cost of plate(I). (Dollars)
CLGCUT	The cost of cutting the flanges of a longitudinal. (Man-Hours per foot)
FRM	Transverse frame spacing. (Feet)

Calculated Items

Symbol	Meaning
TSPAN(I)	Span between longitudinals, for entire section. (Feet)
CWELD(I)	Cost of welding the plating, per butt per foot length. (Dollars)
DIST	Location of plate butts. (Feet)
DSUMS	Locations of longitudinals. (Feet)
LGL1/XLGL1...5	Number of plates (1)...(5) required for midship section.
NOCUT/PTCUT	Number of times plates must be cut.
CPLTWD	Total cost of welding the plating, per foot length. (Dollars)
CPTCUT	Total cost of cutting the plates, per foot length. (Dollars)
TCROLL	Total cost of rolling the plates, per foot length. (Dollars)
CRIG	Total cost of providing the rigging, per foot length. (Dollars)
CPLTNG	Total acquisition cost of the plating, per foot length. (Dollars)
CTLGTL	Total acquisition cost of the longitudinals, per foot length. (Dollars)
CWLTNL	Total welding cost for the longitudinals, per foot length. (Dollars)

Symbol	Meaning
CCUTFT	The calculated cost of cutting the flanges of the longitudinals. (Dollars per foot length)
CTFRAM	Approximate cost per foot hull length for the transverse frame. (Dollars)

Output

Symbol	Meaning
CTOTAL	Total cost of building the midship section, per foot length. (Dollars)

Sample Input/Output (Computer test run)

Input:

	PLT(I,1)	PLT(I,2)	PLT(I,3)
I = 1	8.0	33.0	959.00
2	8.0	20.0	614.00
3	...	....	......
4	...	....	......
5	...	....	......

CWLDMH	1.60	Man-Hours/Foot
THL	0.75	Inches
XLGTNL	17.0	
CHGMNH	7.50	Dollars/Man-Hours
COSTKL	27.56	Dollars/Foot
TOTSPN	125.95	Feet
CROLL	3.90	Dollars
CSTLGL	3.90	Dollars/Foot

	SPAN(I)	SPAN(I+1)	SPAN(I+2)
I = 1	4.717	4.751	4.853
I = 4	5.110	5.724	6.935
I = 5	8.516	9.080	13.291

CWLGTL	0.66	Man-Hours/Foot
CLGCUT	0.14	Man-Hours/Foot
FRM	8.00	Feet

Output: CTOTAL 1466.77 Dollars

Fundamental Equations

$$CWELD(I) = CHGMNH \times ((2 \times (PLT(I,1) + PLT(I,2))) \times \frac{(CWLDMH \times 1.12 + 0.144) + 5.5)}{2.0 \times PLT(I,2)}$$

$$DIST = DIST + PLT(I,1)$$

OR

$$= DIST - 0.7 + PLT(I+1,1)$$

(If too near a longitudinal)

$$CPLTWD = CWELD(1) \times XLGL1 + CWELD(2) \times XLGL2 + CWELD(3) \times XLGL3 + CWELD(4) \times XLGL4 + CWELD(5) \times XLGL5$$

$$CPTCUT = PTCUT \times CHGMNH \times \left(0.05 + \frac{0.01 \times (TH1 - 0.25)}{0.125}\right)$$

$$TCROLL = \frac{CHGMNH}{20.} \times CROLL \times (XLGL1 + XLGL2 + XLGL3 + XLGL4 + XLGL5)$$

$$CRIG = 0.4 \times (20. + 12.4 + 9.7 + 7.5) \times CHGMNH$$

$$CPLTNG = \frac{PLT(1,3) \times XLGL1}{PLT(1,2)} + \frac{PLT(2,3) \times XLGL2}{PLT(2,2)} + \frac{PLT(3,3) \times XLGL3}{PLT(3,2)} + \frac{PLT(4,3) \times XLGL4}{PLT(4,2)} + \frac{PLT(5,3) \times XLGL5}{PLT(5,2)}$$

$$CTLGTL = XLGTNL \times CSTLGL$$

$$CCUTFT = CLGCUT \times XLGTNL \times CHGMNH$$

$$CTFRAM = \frac{0.7 \times COSTKL \times TOTSPN}{FRM}$$

$$CTOTAL = CPLTWD + CPTCUT + TCROLL + CRIG + CPLTNG + CTLGTL + CWLTNL + CCUTFT + CTFRAM + COSTKL$$

Sample Calculation (Refer to program listing, flow chart, and printout of typical computer run, following pages)

```
      DIMENSION PLT(5,3),SPAN(40),TSPAN(80),CWELD(5)
      DO 800 I = 1, 80
  800 TSPAN(I) = 0.0
  900 FORMAT (8F10.6)
      DATA LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT/1,0,0,0,0,2/
  910 FORMAT (8I10)
      DO 400 I = 1, 5
      READ (5, 900) PLT(I,1), PLT(I,2), PLT(I,3)
      WRITE (6, 900) PLT(I,1), PLT(I,2), PLT(I,3)
      IF (PLT(I,1) .LT. 20.0) GO TO 400
      PLT(I,1) = 0.0
      PLT(I,2) = 0.0
      PLT(I,3) = 0.0
  400 CONTINUE
      READ (5,900) CWLDMH,TH1,XLGTNL,CHGMNH,COSTKL,TOTSPN,CROLL,CSTLGL
      WRITE(6,900) CWLDMH,TH1,XLGTNL,CHGMNH,COSTKL,TOTSPN,CROLL,CSTLGL
      DO 410 I = 1, 36, 5
      READ (5,900) SPAN(I), SPAN(I+1), SPAN(I+2), SPAN(I+3), SPAN(I + 4)
  410 WRITE(6,900) SPAN(I), SPAN(I+1), SPAN(I+2), SPAN(I+3), SPAN(I + 4)
      READ(5,900) CWLGTL,CLGCUT,FRM
      WRITE (6, 900) CWLGTL, CLGCUT, FRM
      DO 420 I = 1, 40
      TSPAN(I) = SPAN(I)
      IF(SPAN(I) .EQ. 0.0) GO TO 425
  420 CONTINUE
  425 IF (I .EQ. 40) GO TO 426
      DO 430 J = 1, 40
      TSPAN(I + J - 1) = SPAN(I - J)
      IF ((I-J-1) .EQ. 0) GO TO 435
  430 CONTINUE
  426 DO 431 J = 1, 40
  431 TSPAN(I + J) = SPAN(I - J + 1)
C
C     CALCULATE THE COST OF WELDING THE PLATING (PER BUTT PER FT. LGTH.)
C
  435 DO 440 I = 1, 5
      IF (PLT(I,1) .EQ. 0.0) GO TO 445
  440 CWELD(I) = CHGMNH * ((2.0*(PLT(I,1)+PLT(I,2)))*(CWLDMH*1.12 + 0.14
     14) + 5.5)/(PLT(I,2)*2.0)
  445 DO 446 J = I, 5
  446 CWELD(J) = 0.0
C
C     CALCULATE THE NUMBER OF PLATES OF EACH SIZE USED FOR THE MIDSHIP
C     SECTION.
C
      DSUMS = 0.0
      I = 1
      J = 1
```

```
      DIST = 0.5 * PLT(1,1)
  933 FORMAT('0    DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT')
  934 FORMAT (2(F10.6,4X),7(I3,4X))
  460 DSUMS = DSUMS + TSPAN(J)
      WRITE (6, 933)
      WRITE(6,934) DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
      IF ((TOTSPN - DIST) .LT. (0.5*PLT(1,1))) GO TO 600
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 450
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 452
      IF (PLT(2,1) .EQ. 0.0) GO TO 455
      DIST = DIST - PLT(1,1) + PLT(2,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 470
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 472
      IF (PLT(3,1) .EQ. 0.0) GO TO 475
      DIST = DIST - PLT(2,1) + PLT(3,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 480
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 482
      IF (PLT(4,1) .EQ. 0.0) GO TO 485
      DIST = DIST - PLT(3,1) + PLT(4,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 490
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 492
      IF (PLT(5,1) .EQ. 0.0) GO TO 495
      DIST = DIST - PLT(4,1) + PLT(5,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 510
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 512
      DIST = DIST - 0.7 + PLT(1,1)
      LGL5 = LGL5 + 1
      NOCUT = NOCUT + 1
      J = J + 1
      GO TO 460
  450 J = J + 1
      GO TO 460
  452 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL1 = LGL1 + 1
      GO TO 460
  455 DIST = DIST - 0.7 + PLT(1,1)
      LGL1 = LGL1 + 1
      NOCUT = NOCUT + 1
      J = J + 1
      GO TO 460
  470 J = J + 1
      LGL2 = LGL2 + 1
      GO TO 460
  472 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL2 = LGL2 + 1
      GO TO 460
```

```
  475 DIST = DIST - 0.7 + PLT(1.1)
      NOCUT = NOCUT + 1
      LGL2 = LGL2 + 1
      J = J + 1
      GO TO 460
  480 J = J + 1
      LGL3 = LGL3 + 1
      GO TO 460
  482 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL3 = LGL3 + 1
      GO TO 460
  485 DIST = DIST - 0.7 + PLT(1,1)
      NOCUT = NOCUT + 1
      LGL3 = LGL3 + 1
      J = J + 1
      GO TO 460
  490 J = J + 1
      LGL4 = LGL4 + 1
      GO TO 460
  492 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL4 = LGL4 + 1
      GO TO 460
  495 DIST = DIST - 0.4 - 0.3 + PLT(1,1)
      NOCUT = NOCUT + 1
      LGL4 = LGL4 + 1
      J = J + 1
      GO TO 460
  510 J = J + 1
      LGL5 = LGL5 + 1
      GO TO 460
  512 DIST = DIST + PLT(1,1)
      LGL5 = LGL5 + 1
      J = J + 1
      GO TO 460
  515 DIST = DIST + PLT(1,1) - 0.7
      LGL5 = LGL5 + 1
      NOCUT = NOCUT + 1
      J = J + 1
      GO TO 460
  600 NOCUT = NOCUT + 1
      XLGL1 = LGL1
      XLGL2 = LGL2
      XLGL3 = LGL3
      XLGL4 = LGL4
      XLGL5 = LGL5
      CPLTWD = CWELD(1)*XLGL1 + CWELD(2)*XLGL2 + CWELD(3)*XLGL3 +
```

```
     1CWELD(4)*XLGL4 + CWELD(5)*XLGL5
C
C     DETERMINE THE COST OF CUTTING THE PLATES.
C
      PTCUT = NOCUT
      CPTCUT = PTCUT * CHGMNH * (0.05 + 0.01*((TH1-0.25)/0.125))
C
C     DETERMINE THE COST OF ROLLING THE PLATES.
C
      TCROLL = CHGMNH * CROLL * (XLGL1+XLGL2+XLGL3+XLGL4+XLGL5)/20.0
C
C     CALCULATE THE COST OF PROVIDING STAGING.
C     HEIGHT OF 20', 14', 8', AND 3', TWO EACH, ARE PROVIDED.
C
      CRIG = 0.4 * (20.0 + 12.4 + 9.7 + 7.5) * CHGMNH
C
C     NOW CALCULATE THE ACQUISITION COST FOR THE PLATING.
C
      CPLTNG = PLT(1,3)*XLGL1/PLT(1,2) + PLT(2,3)*XLGL2/PLT(2,2) +
     1 PLT(3,3)*XLGL3/PLT(3,2) + PLT(4,3)*XLGL4/PLT(4,2) +
     2 PLT(5,3)*XLGL5 / PLT(5,2)
C
C     NOW CALCULATE THE ACQUISITION COST FOR THE LONGITUDINALS.
C
      CTLGTL = XLGTNL * CSTLGL
C
C     CALCULATE THE WELDING COST FOR THE LONGITUDINALS.
C
      CWLTNL = XLGTNL * CHGMNH *(CWLGTL*1.12 + 0.151)
C
C     CALCULATE THE COST OF CUTTING THE FLANGES OF THE LONGITUDINALS.
C
      CCUTFT = CLGCUT * XLGTNL * CHGMNH
C
C     CALCULATE THE APPROXIMATE COST (PER FOOT HULL LENGTH) FOR THE TRANSVE
C     FRAME.  ESTIMATE THAT, PER FT. GIRTH, CFRAME = 0.7 * COSTKL.
C
      CTFRAM = 0.7 * COSTKL * TOTSPN / FRM
C
C     CALCULATE THE TOTAL COST OF BUILDING THE MIDSHIP SECTION, DOLLARS
C     PER FOOT HULL LENGTH.
C
      CTOTAL = CPLTWD + CPTCUT + TCROLL + CRIG + CPLTNG + CTLGTL +
  →  1 CWLTNL + CCUTFT + CTFRAM + COSTKL
  920 FORMAT ('1     CPLTWD =',F15.6)
  921 FORMAT ('0     CPTCUT =',F15.6)
  922 FORMAT ('0     TCROLL =',F15.6)
  923 FORMAT ('0     CRIG   =',F15.6)
```

```
  924 FORMAT ('0     CPLTNG =',F15.6)
  925 FORMAT ('0     CTLGTL =',F15.6)
  926 FORMAT ('0     CWLTNL =',F15.6)
  927 FORMAT('0     CCUTFT =',F15.6)
  928 FORMAT ('0     CTFRAM =',F15.6)
  929 FORMAT ('0     CTOTAL =',F15.6)
  930 FORMAT ('0     LGL1 =',I2,'  LGL2 =',I2,'  LGL3 =', I2,'  LGL4 =',
     1 I2,'  LGL5 =', I2)
  931 FORMAT ('0     XLGL1 =',F5.2,'  XLGL2 =', F5.2,' XLGL3 =', F5.2,'
     1XLGL4 =', F5.2,' XLGL5 =', F5.2)
  932 FORMAT ('0     CWELD(I) =',5(F8.3,5X))
      WRITE (6, 932) CWELD(1), CWELD(2), CWELD(3), CWELD(4), CWELD(5)
      WRITE (6, 920) CPLTWD
      WRITE (6, 921)CPTCUT
      WRITE (6, 922) TCROLL
      WRITE (6, 923) CRIG
      WRITE (6, 930) LGL1, LGL2, LGL3, LGL4, LGL5
      WRITE (6, 931) XLGL1, XLGL2, XLGL3, XLGL4, XLGL5
      WRITE (6, 924) CPLTNG
      WRITE (6, 925) CTLGTL
      WRITE (6, 926) CWLTNL
      WRITE (6, 927) CCUTFT
      WRITE (6, 928)  CTFRAM
      WRITE (6, 929) CTOTAL
      STOP
      END
```

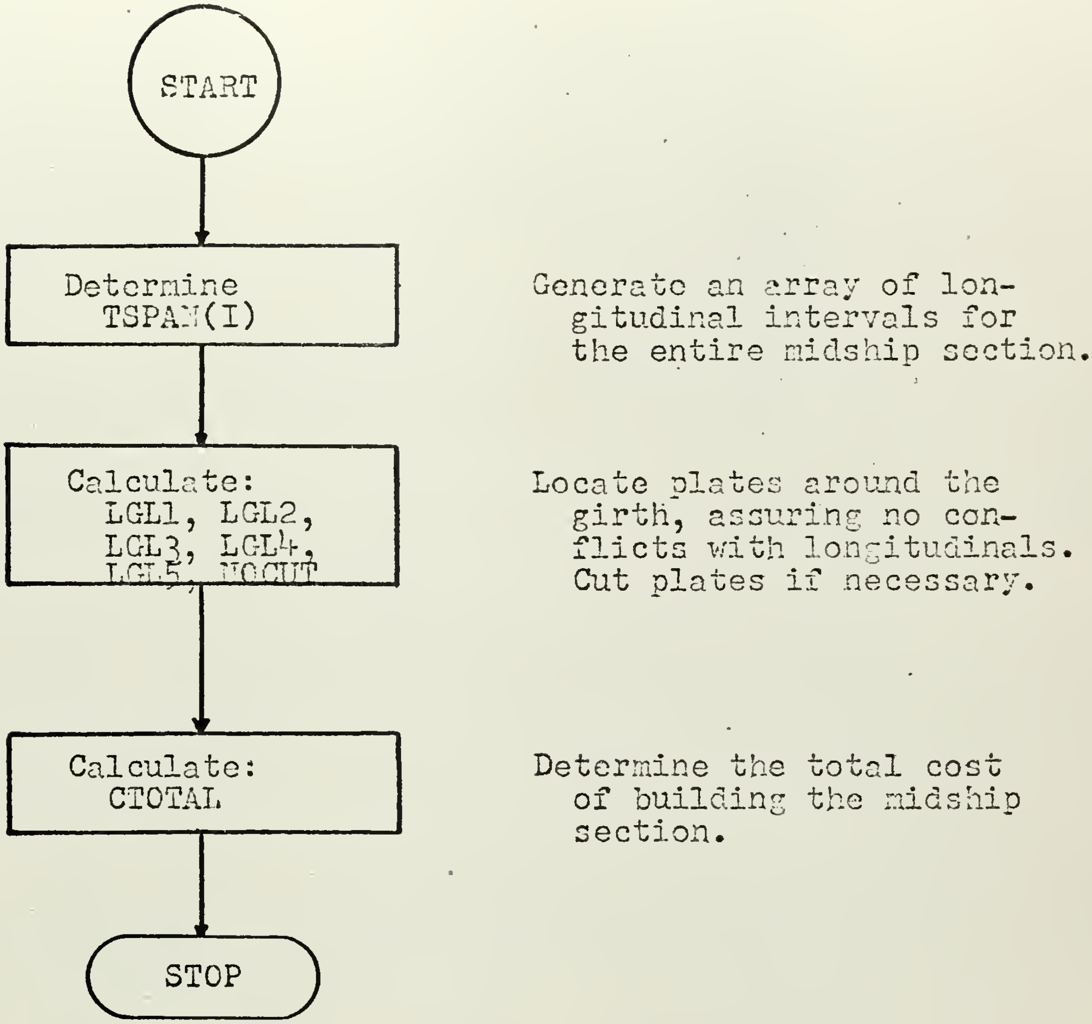


FIGURE IV

MAIN PROGRAM COSTDATA FLOW CHART

```
IEF285I   SYS1.UT1                                                KEPT
IEF285I   VOL SER NOS= CCSY03.
IEF285I   SYS1.FORTLIB                                            KEPT
IEF285I   VOL SER NOS= CCSY02.
IEF285I   SYS1.SSPLIB                                             KEPT
IEF285I   VOL SER NOS= CCSY03.
IEF285I   SYS1.MITLIB                                             KEPT
IEF285I   VOL SER NOS= CCSY03.
IEF285I   LMOD.COSTDATA                                           PASSED
IEF285I   VOL SER NOS= CCSY01.
IEF285I   TEMP.COSTDATA                                           PASSED
IEF285I   VOL SER NOS= CCSY01.
IEF285I   SYSOUT                                                  SYSOUT
IEF285I   VOL SER NOS= .
******    END OF STEP L           PGM = IEWL      70606.33  *******
//G        EXEC  PGM=*.L.SYSLMOD,COND=(4,LT)                                00000170
//SYSPRINT DD       SYSOUT=A                                                00000180
//FT05F001 DD     DDNAME=SYSIN                                              00000190
//FT06F001 DD      SYSOUT=A                                                 00000200
//FT07F001 DD      UNIT=SYSCP                                               00000210
//G.SYSIN DD   *
IEF236I ALLOC. FOR COSTDATA G          SN1
IEF237I PGM=*.DD ON 191
IEF237I FT05F001 ON 20C
IEF237I FT07F001 ON 20D

 8.000000 33.000000959.000000
 8.000000 20.000000614.000000
 0.0        0.0        0.0
 0.0        0.0        0.0
 0.0        0.0        0.0
 1.599999   0.750000  17.000000   7.500000  27.559998125.947998   3.900000   3.900000
 4.717299   4.750799   4.652599   5.109500   5.724000
 6.934500   8.516100   9.079700  13.291200   0.0
 0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
 0.660000   0.140000   8.000000

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
 4.000000        4.717299      1       1       0       0       0       0       2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
12.000000        9.468099      2       2       0       0       0       0       2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
12.000000       14.320695      3       2       0       0       0       0       2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
20.000000       19.430191      4       3       0       0       0       0       2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
20.000000       25.154190      5       3       0       0       0       0       2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
28.000000       32.083654      6       4       0       0       0       0       2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
44.000000     49.684479     8     6     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
52.000000     62.975677     9     7     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
60.000000     76.266376    10     8     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
68.000000     85.346573    11     9     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
76.000000     93.862671    12    10     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
84.000000    100.797165    13    11     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
92.000000    106.521164    14    12     0     0     0     0     2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
00.000000    111.630661    15    13    0    0    0    0    2
DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
8.000000    115.483246    16    14    0    0    0    0    2
DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
6.000000     121.234034     17     15     0     0     0     0     2
 DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
24.000000    125.951324    18    16    0    0    0    0    2
IHC210I PROGRAM INTERRUPT--OLD PSW IS    FF150000FA200A938
IHC210I PROGRAM INTERRUPT--OLD PSW IS    FF15000FA200A944
IHC210I PROGRAM INTERRUPT--OLD PSW IS    FF15000FA200A952
   CWELD(1) =  15.665      21.359      0.0      0.0      0.0
```

```
CPLTWD =      298.559548

CPTCUT =        2.024994

TCROLL =       23.599979

CRIG   =      148.799850

LGL1 =16  LGL2 = 0  LGL3 = 0  LGL4 = 0  LGL5 = 0

XLGL1 =16.00  XLGL2 = 0.0  XLGL3 = 0.0  XLGL4 = 0.0  XLGL5 = 0.0

CPLTNG =      464.969482

CTLGTL =       66.299988

CWLTNL =      113.500473

CCUTFT =       17.349991

CFFRAM =      303.723389
COSTKL =       27.559998
CTOTAL =     1439.207031
           #  1466.767029
```

C. SUBROUTINE TSLECT

1. DESCRIPTION

Introduction

Given the minimum tolerable spacing of longitudinals and the design stress criteria, this subroutine calculates the required plating thickness using criteria for the critical stress and tertiary stress levels. These two thicknesses are then compared, and the greater selected. This exact value of thickness is then used to select the minimum standard plate thickness that will satisfy the design requirements, and the minimum spacing is modified by the ratio of the selected thickness to the required thickness. This span is then used as the initial longitudinal spacing.

Inputs

Symbol	Meaning
W5BMIN	Minimum permissible longitudinal spacing. (Feet)
ST1CRK	Maximum permissible stress at keel. (Tons/In.^{2})
ST2EST	Estimated value of secondary stress. (Tons/In.^{2})
SGMULT	Yield stress of the plating. (Tons/In.^{2})
FRM	Transverse frame spacing. (Feet)

Calculated Items

Symbol	Meaning
SGMACR	Limiting stress intensity, defined as 1.25 x (ST1CAL + ST2EST) (Tons/In.^{2})
ABAB	Plate aspect ratio.
C1CRIT	Coefficient used in calculating the critical strength of the plating.
CC1	Intermediate calculation used in determining the required plating thickness based on critical stress criteria.
THPRIM	Plating thickness required to satisfy critical stress criteria. (Inches)
PRESS	Hydrostatic pressure at keel. (Tons/In.^{2})
C3CRIT	Coefficient used in calculating the tertiary stress strength of the plating. (Tons/In.^{2})
ST3MAX	Maximum tolerable intensity of the tertiary stress. (Tons/In.^{2})
CC3	Intermediate calculation used in determining the required plating thickness based on tertiary stress criteria.
THTER	Plating thickness required to satisfy tertiary stress criteria. (Inches)
TH	The greater of THPRIM or THTER. (Inches)

Output

Symbol	Meaning
TH1	Plating thickness selected. This is the least existing thickness that exceeds the value TH. (Inches)
W5BACT	Tolerable longitudinal spacing for selected plating thickness. (Feet)

Calling Sequence

Call TSLECT (W5BMIN, ST1CRK, ST2EST, SGMULT, FRM, TH1, W5BACT)

Sample Input/Output (Computer test run)

Input:	W5BMIN	1.667	Feet
	ST1CRK	7.93	Tons/In.^{2}
	ST2EST	1.34	Tons/In.^{2}
	SGMULT	20.98	Tons/In.^{2}
	FRM	8.00	Feet
Output:	TH1	0.28125	Inches
	W5BACT	1.769	Feet

Fundamental Equations

$$ABAB = \frac{FRM}{W5BMIN}$$

$$CC1 = \sqrt{\frac{C1CRIT \times 3.1416^2 \times 13392.857}{10.9 \times SGMACR}}$$

$$THPRIM = \frac{12.0 \times W5BMIN}{CC1}$$

$$PRESS = \frac{0.445 \times HM}{2240.}$$

$$CC3 = \sqrt{\frac{ST3MAX}{5.46 \times C3CRIT \times PRESS}}$$

$$THTER = \frac{12 \times W5BMIN}{CC3}$$

$$W5BACT = \frac{TH1 \times W5BMIN}{TH}$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$SGMACR = \underline{11.58}$

$ABAB = \underline{4.80}$

$C1CRIT = \underline{7.225}$

$$CC1 = \sqrt{\frac{(7.225 \times 9.87 \times 13392.857)}{126.4}} = \underline{86.9}$$

$$THPRIM = \frac{20}{86.9} = \underline{0.230}$$

$HM = \underline{30.23}$

PRESS = $\underline{0.00601}$

C3CRIT = $\underline{0.0627}$

ST3MAX = $\underline{11.71}$

$$CC3 = \sqrt{\frac{11.71}{5.46 \times .0627 \times .00601}}$$
$$= \underline{75.7}$$

$$THTER = \frac{20}{75.7} = \underline{0.264}$$

TH = $\underline{0.264}$

TH1 = $\underline{0.28125}$ inches

$$W5BACT = \frac{0.28125}{0.264} \times 1.667$$
$$= \underline{1.77} \text{ feet}$$

```
      SUBROUTINE TSLECT(W5BMIN,ST1CRK,ST2EST,SGMULT,FRM,TH1,W5BACT)
      SGMACR = 1.25 * (ST1CRK + ST2EST)
      ABAB = FRM / W5BMIN
      IF (ABAB - 7.0) 701, 703, 703
  703 C1CRIT = 7.0
      GO TO 780
  701 IF (ABAB - 3.5) 702, 704, 704
  704 C1CRIT = 7.0 + 0.4 * ((7.0 - ABAB)/3.5)
      GO TO 780
  702 IF(ABAB - 1.9) 705, 706, 706
  706 C1CRIT = 7.4 + 0.7 * (3.5 - ABAB)/1.6
      GO TO 780
  705 C1CRIT = 8.1 - (ABAB - 1.9) / 1.9
  780 ADULIN = C1CRIT * 3.1416 * 3.1416 * 13392.86
      BDULIN = 10.9 * SGMACR
      CC1 = SQRT (ADULIN/BDULIN)
      ST1CAL = ST1CRK
      THPRIM = (W5BMIN * 12.) / CC1
      YPTMIN = 0.0
      ZPTMIN = 0.0
C     TERTIARY STRESS CALCULATION
C
      A3HEEL = 0.5236
      D1 = 26.231247
      H1AMDK = 4.0
      H1DFL = 14.5
      XL1BP = 407.
      NBELTS = 1
      CALL HDWTR (A3HEEL,YPTMIN,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZPTMIN,HM)
      PRESS = (0.445 * HM) / 2240.
      IF (ABAB - 1.4) 901, 903, 903
  903 C3CRIT = 0.0627
      GO TO 980
  901 IF (ABAB - 1.2) 902, 904, 904
  904 C3CRIT = 0.0615 + 0.0012 * ((ABAB - 1.2) / 0.2)
      GO TO 980
  902 C3CRIT = 0.057 + 0.0009 * (ABAB - 1.0)
  980 ST3MAX = SGMULT - ST1CAL - ST2EST
      CC3 = SQRT (ST3MAX / (5.46 * C3CRIT * PRESS))
      THTER = (12.0 * W5BMIN) / CC3
      IF (THTER .GT. THPRIM) GO TO 600
      TH = THPRIM
      GO TO 16
  600 TH = THTER
   16 IF((TH - 0.375).GT. 0) GO TO 401
  405 IF ((TH - 0.25) .GT. 0) GO TO 407
      TH1 = 0.25
      GO TO 900
```

```
  407 IF ((TH - 0.28125) .GT. 0) GO TO 409
      TH1 = 0.28125
      GO TO 900
  409 IF((TH - 0.3125) .GT. 0) GO TO 411
      TH1 = 0.3125
      GO TO 900
  411 IF ((TH - 0.34375) .GT. 0) GO TO 413
      TH1 = 0.34375
      GO TO 900
  413 TH1 = 0.375
      GO TO 900
  401 IF((TH1 - 1.0).GT. 0) GO TO 501
    . IF((TH - 0.4375).GT. 0) GO TO 503
      TH1 = 0.4375
      GO TO 900
  503 IF((TH - 0.50) .GT. 0) GO TO 505
      TH1 = 0.500
      GO TO 900
  505 IF ((TH - 0.625) .GT. 0) GO TO 507
      TH1 = 0.625
      GO TO 900
  507 IF((TH - 0.75).GT. 0) GO TO 509
      TH1 = 0.75
      GO TO 900
  509 IF((TH - 0.875) .GT. 0) GO TO 511
      TH1 = 0.875
      GO TO 900
  511 IF((TH - 0.9375) .GT. 0) GO TO 513
      TH1 = 0.9375
      GO TO 900
  513 TH1 = 1.000
   17 FORMAT ('REQUIRED PLATING THICKNESS EXCEEDS ONE INCH.')
  501 WRITE (6, 17)
  900 W5BACT = (TH1 * W5BMIN) / TH
      RETURN
      END
```

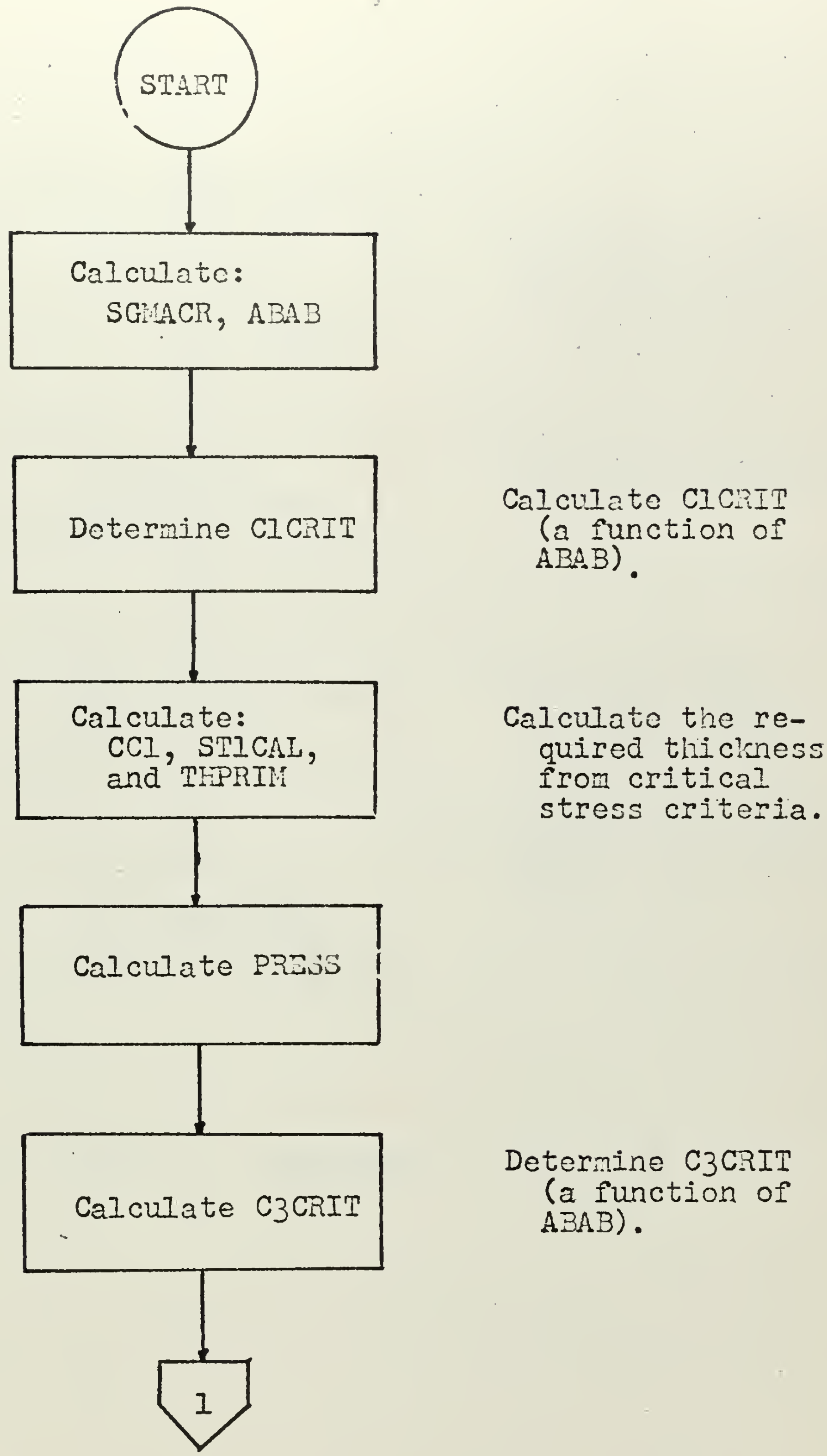
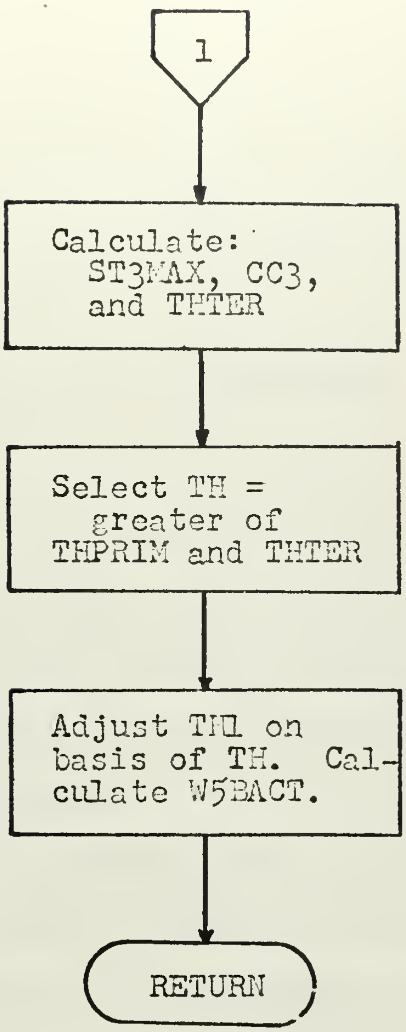


FIGURE V

SUBROUTINE TSLECT FLOW CHART



Determine the requir-
ed plating thick-
ness from tertiary
stress criteria.

Select the required
plating thickness.

Select the least
existing plating
thickness that
satisfies the TH
requirement. De-
termine the allow-
able longitudinal
span.

FIGURE V - Continued

D. SUBROUTINE HDWTR*

1. DESCRIPTION

Introduction

This subroutine calculates the maximum hydrostatic head of water existing at a designated point on the shell. Three loading conditions are evaluated, using current procedures employed by the Naval Ship Systems Command in the design of ships:

1. The maximum head is calculated for the effects of the full load draft with half the height of a standard wave profile superposed.
2. The maximum head is calculated for the condition of the ship at full load draft heeled over some specified angle. In the case of this analysis, the heel angle is fixed at thirty degrees.
3. Finally, the maximum head resulting from the superposition of a specified design head of water on the main deck is computed.

---

*Subroutine HDWTR is based on a subroutine of the same name developed by the Applied Mathematics Laboratory of the David Taylor Model Basin, Washington, D. C. 20007.

After the individual heads are determined for the various conditions, the maximum value is selected as the output from the subroutine.

Inputs

Symbol	Meaning
A3HEEL	Specified maximum heel angle. (Radians)
B3P	Half breadth of point. (Feet)
D1	Depth of hull. (Feet)
H1AMDK	Specified design head of water above main deck. (Feet)
H1DFL	Design full load draft. (Feet)
NBELTS	Number of points. (= 1)
XL1BP	Length between perpindiculars. (Feet)
ZK1P	Height of point above keel. (Feet)

Calculated Items

Symbol	Meaning
HMAMDK	Head of water due to design head of water on main deck. (Feet)
HMHEEL	Head of water due to heel. (Feet)
HMO	Head of water due to wave profile. (Feet)
H1	Draft due to standard wave profile. (Feet)
THM	Draft due to head of water above main deck. (Feet)

Output

Symbol	Meaning
HM	Maximum head of water to point. (Feet)

Calling Sequence

Call HDWTR (A3HEEL, B3P, D1, H1AMDK, H1DFL, NBELTS, XL1BP, ZK1P, HM)

Sample Input/Output (Computer test run)

Input:	A3HEEL	0.5236	radians
	B3P	39.83	feet
	D1	70.00	feet
	H1AMDK	0.00	feet
	H1DFL	26.00	feet
	NBELTS	1	
	XL1BP	580.00	feet
	ZK1P	14.00	feet
Output:	HM	30.31	feet

Fundamental Equations

$$H1 = H1DFL + 0.55 \times \sqrt{XL1BP}$$

$$HM0 = H1 - ZK1P$$

$$HMHEEL = D \times Cos\ (1.5708 - B - A3HEEL)$$

$$B = Arctan\ \frac{H1DFL - ZK1P}{B3P}$$

$$D = \sqrt{B3P^2 + (H1DFL - ZK1P)^2}$$

$$HMAMDK = THM - ZK1P$$

$$THM = D1 + H1AMDK$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$$H1 = 26.00 + 0.55 \times 24.08319$$
$$= \underline{39.2458}$$

$$HM0 = 39.2458 - 14.0$$
$$= \underline{25.2458}$$

$$D = \sqrt{1585.43 + 144}$$
$$= \underline{41.53}$$

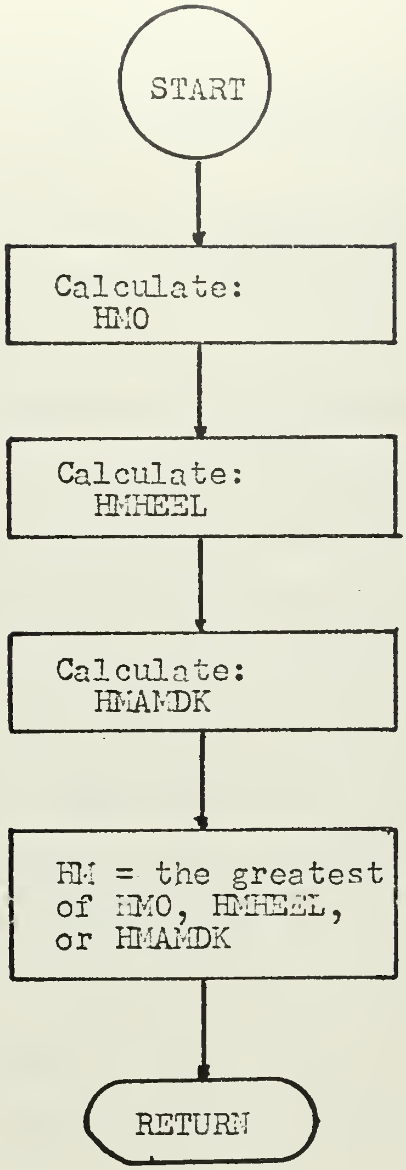
$$B = Arctan\ (0.3012)$$
$$= \underline{0.2926}$$

$$HMHEEL = 41.53 \times Cos\ (0.7546)$$
$$= \underline{30.31}$$

$$HM = HMHEEL = \underline{30.31} \text{ feet}$$

```
      SUBROUTINE HDWTR(A3HEEL,B3P,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZK1P,HM)
C
C     CALCULATE DRAFT TO STANDARD WAVE HEIGHT
C
      H1 = H1DFL + 0.55*SQRT(XL1BP)
      IF(ZK1P - H1) 1,2,2
    1 HMO = H1 - ZK1P
      GO TO 3
    2 HMO = 0.0
C
C     CALCULATE HEAD OF WATER DUE TO HEELED WATERLINE
C
    3 IF (ZK1P - H1DFL) 4,7,5
    4 D = SQRT(B3P**2 + (H1DFL - ZK1P)**2)
      IF (B3P) 19,19,18
   19 B = 1.5708
      GO TO 20
   18 B = ATAN ((H1DFL - ZK1P)/B3P)
   20 IF (B - 1.5708 + A3HEEL) 15, 16, 17
   15 HMHEEL = D*COS(1.5708 - A3HEEL - B)
      GO TO 10
   16 HMHEEL = D
      GO TO 10
   17 HMHEEL = D*COS(B - 1.5708 + A3HEEL)
      GO TO 10
    5 D = SQRT (B3P**2 + (ZK1P - H1DFL)**2)
      B = ATAN ((ZK1P - H1DFL)/B3P)
      IF ( B - A3HEEL) 6,8,8
    6 HMHEEL = D*COS(1.5708 - A3HEEL + B)
      GO TO 10
    7 HMHEEL = B3P * SIN(A3HEEL)
      GO TO 10
    8 HMHEEL = 0.0
C
C     COMPARE HEADS CALCULATED THUS FAR AND DETERMINE THE MAXIMUM
C
   10 IF (HMO - HMHEEL) 11, 12, 12
   11 HM = HMHEEL
      GO TO 100
   12 HM = HMO
  100 CONTINUE
      IF(H1AMDK) 40,40,41
C
C     CALCULATE DRAFT DUE TO HEAD OF WATER ABOVE MAIN DECK
C
   41 THM = D1 + H1AMDK
      HMAMDK = THM - ZK1P
C
```

```
C       COMPARE HEADS AND DETERMINE FINAL MAXIMUM HEAD AT POINT
C
        IF (HMAMDK - HM) 45,45,46
     46 HM = HMAMDK
     45 CONTINUE
     40 RETURN
        END
```



Calculate the head due to the standard wave profile.

Calculate the head due to the specified heel angle.

Calculate the head due to the design head of water above the main deck.

Select the maximum hydrostatic head acting at the point.

FIGURE VI

SUBROUTINE <u>HDWTR</u> FLOW CHART

E. SUBROUTINE CSPACE

1. DESCRIPTION

Introduction

This subroutine calculates the maximum permissible span to the next (upper) longitudinal on the midship section. The hydrostatic head existing at the lower edge of the span is employed for this calculation. The permissible spacing is calculated on the basis of three different criteria, as described by St. Denis [1] :

1. The permissible span is calculated on the basis of the maximum compressive stress exerted on the plating.
2. The permissible span is calculated on the basis of the tolerable tertiary stress level - caused by plate binding due to hydrostatic pressure normal to the plate surface.
3. Finally, stability requirements for the unsupported plate are used to evaluate the permissible span between longitudinals.

Once the three values of the tolerable span have been determined, the lesser value of the three is selected as the limiting span.

Inputs

Symbol	Meaning
ST1CRK	Maximum permissible stress at keel. (Tons/In.^{2})
ST1CRD	Maximum permissible stress at deck centerline. (Tons/In.^{2})
ST2EST	Estimated value of secondary stress. (Tons/In.^{2})
SGMULT	Yield stress of the plating. (Tons/In.^{2})
FRM	Transverse frame spacing. (Feet)
TH1	Plating thickness. (Inches)
YPTMIN	Half breadth of preceding longitudinal. (Feet)
ZPTMIN	Height of preceding longitudinal above base line. (Feet)
W5BPRC	Span to preceding longitudinal. (Feet)

Calculated Items

Symbol	Meaning
ZNAXIS	Location of neutral axis of DD-931 midship section above base line. (Feet)
ST1CAL	Calculated primary compressive stress at preceding longitudinal. (Feet)
SGMACR	Limiting stress intensity, defined as 1.25 x (ST1CAL + ST2EST) (Tons/In.^{2})
ABAB	Aspect ratio of preceding span.
C1CRIT	Coefficient used in calculating the critical strength of the plating.
W5BTL1	Permissible span due to critical strength criteria. (Feet)
PRESS	Hydrostatic pressure at preceding longitudinal. (Tons/In.^{2})
C3CRIT	Coefficient used in the tertiary stress calculation.

Symbol	Meaning
W5BTL3	Permissible span due to the tertiary stress calculation. (Feet)
SGMCRT	Critical stress intensity for a panel of plating. (Tons/In.^{2})
XNOSTF	Required number of stiffeners for a plate panel.
ST3MAX	Greatest tolerable tertiary stress. (Tons/In.^{2})
W5BTLS	Tolerable span on basis of plate stability criteria. (Feet)

Output

Symbol	Meaning
W5BTOL	Maximum tolerable span to next longitudinal. (Feet)

Calling Sequence

Call CSPACE (ST1CRK, ST1CRD, ST2EST, SGMULT, FRM, TH1, YPTMIN, ZPTMIN, W5BPRC, W5BTOL)

Sample Input/Output (Computer test run)

Input:	ST1CRK	7.93	Tons/In.^{2}
	ST1CRD	6.00	Tons/In.^{2}
	ST2EST	1.34	Tons/In.^{2}
	SGMULT	20.98	Tons/In.^{2}
	FRM	8.00	Feet
	TH1	0.28125	Inches
	YPTMIN	1.768	Feet
	ZPTMIN	0.045	Feet
	W5BPRC	1.769	Feet
Output:	W5BTOL	1.772	Feet

Fundamental Equations

$$\text{ZNAXIS} = 26.23125 \times \left(\frac{\text{ST1CRK}}{\text{ST1CRK} + \text{ST1CRD}} \right)$$

$$\text{ST1CAL} = \text{ST1CRK} \times \left| \frac{\text{ZNAXIS} - \text{ZPTMIN}}{\text{ZNAXIS}} \right|$$

$$ABAB = FRM/W5BPRC$$

$$W5BTL1 = \frac{TH1 \times CC1}{12.0}$$

$$CC1 = \sqrt{\frac{C1CRIT \times 3.1416^2 \times 13392.86}{10.9 \times SGMACR}}$$

$$PRESS = 0.445 \times HM/2240.$$

$$ST3MAX = SGMULT - ST1CAL - ST2EST$$

$$W5BTL3 = \frac{TH1 \times CC3}{12.0}$$

$$CC3 = \sqrt{\frac{ST3MAX}{5.46 \times C3CRIT \times PRESS}}$$

$$SGMCRT = \frac{4.0 \times 3.1416^2 \times 13392.86 \times TH1^2}{10.8 \times 3600.}$$

$$XNOSTF = \sqrt{\frac{SGMACR}{SGMCRT}} - 1.0$$

$$W5BTLS = \frac{5.0}{XNOSTF}$$

<u>Sample</u> <u>Calculation</u> (Refer to subroutine listing and flow chart, following pages)

$$ZNAXIS = 26.23125 \times \frac{7.93}{13.93}$$
$$= \underline{14.93}$$

$$ST1CAL = 7.93 \times \left(\frac{14.885}{14.93}\right)$$
$$= \underline{7.90}$$

$$ABAB = 8.0/1.769$$
$$= \underline{4.52}$$

$$CC1 = \sqrt{\frac{7.283 \times 3.1416^2 \times 13392.86}{10.9 \times 11.56}}$$
$$= \underline{87.5}$$

$$W5BTL1 = \frac{0.28125 \times 87.5}{12.0}$$
$$= \underline{2.05}$$

$$PRESS = 0.445 \times 30.19/2240$$
$$= \underline{0.006}$$

$$ST3MAX = \underline{11.74}$$

$$CC3 = \sqrt{\frac{11.74}{5.45 \times .0627 \times .006}}$$
$$= \underline{75.7}$$

$$W5BTL3 = \frac{0.28125 \times 75.7}{12.0}$$
$$= \underline{1.772}$$

$$SGMCRT = \underline{1.076}$$

$$XNOSTF = \sqrt{\frac{11.56}{1.076}} - 1.0$$
$$= \underline{2.28}$$

$$W5BTLS = \underline{2.245}$$

$$W5BTOL = \underline{1.772} \text{ feet}$$

```
      SUBROUTINE CSPACE (ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,YPTMIN,
     1ZPTMIN,W5BPRC,W5BTOL)
C
C     W5BTOL IS CALCULATED ON THE BASIS OF THE PRIMARY AND TERTIARY
C     STRESSES.  THE LESSER VALUE OF THE TWO IS THEN SELECTED.
C     THIS VALUE OF W5BTOL IS THEN COMPARED WITH THE MINIMUM SPAN
C     PERMITTED ON THE BASIS OF THE REQUIRED NUMBER OF STIFFENERS FOR A
C     PLATE WITH THICKNESS TH1 AND A WIDTH OF 5.0 FEET.
C
C     BASIC METHODOLOGY OF SUBROUTINE TSLECT IS USED FOR THE PRIMARY STRESS
C     CALCULATION.
C
      ZNAXIS = 26.23125 * (ST1CRK / (ST1CRK + ST1CRD))
      ST1CAL = ST1CRK * ABS ((ZNAXIS - ZPTMIN)/ZNAXIS)
      SGMACR = 1.25*(ST1CAL + ST2EST)
      ABAB = FRM / W5BPRC
      IF (ABAB - 7.0) 701, 703, 703
  703 C1CRIT = 7.0
      GO TO 780
  701 IF (ABAB - 3.5) 702, 704, 704
  704 C1CRIT = 7.0 + (0.4*((7.0-ABAB)/3.5))
      GO TO 780
  702 IF (ABAB-1.9) 705, 706, 706
  706 C1CRIT = 7.4 + 0.7*(3.5-ABAB)/1.6
      GO TO 780
  705 C1CRIT = 8.1 - (ABAB-1.9)/1.9
  780 ADULIN = C1CRIT * 3.1416 * 3.1416 * 13392.86
      BDULIN = 10.9 * SGMACR
      CC1 = SQRT (ADULIN/BDULIN)
      W5BTL1 = (TH1 * CC1)/ 12.
C
C     TERTIARY STRESS CALCULATION.
C
      DATA A3HEEL,D1,H1AMDK,H1DFL,NBELTS,XL1BP/.5236,26.23125,4.,14.5,1,
     1 407./
      CALL HDWTR (A3HEEL,YPTMIN,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZPTMIN,HM)
      PRESS = 0.445 * HM/2240.
      IF(ABAB - 1.4) 901, 903, 903
  903 C3CRIT = 0.0627
      GO TO 980
  901 IF(ABAB-1.2) 902, 904, 904
  904 C3CRIT = 0.0615 + 0.0012*((ABAB-1.2)/0.2)
      GO TO 980
  902 C3CRIT = 0.057 +  0.0225*(ABAB-1.0)
  980 ST3MAX = SGMULT - ST1CAL - ST2EST
      CC3 = SQRT (ST3MAX/(5.46*C3CRIT*PRESS))
      W5BTL3 = TH1 * CC3 / 12.0
      IF (W5BTL1 .GT. W5BTL3) GO TO 410
```

```
      W5BTOL = W5BTL1
      GO TO 600
  410 W5BTOL = W5BTL3
C
C     PROVIDE FOR ADEQUATE PLATE STABILITY BY LIMITING W5BTOL ON THE
C     BASIS OF THE NUMBER OF STIFFENERS REQUIRED FOR A PLATE WITH A
C     WIDTH OF FIVE FEET.
C
  600 SGMCRT=4.*(3.1416**2)*13392.86*(TH1**2)/(10.8 * 3600.)
      XNOSTF = SQRT (SGMACR / SGMCRT ) -  1.0
      W5BTLS = ABS (5.0/XNOSTF)
      IF (W5BTOL .LT. W5BTLS) GO TO 601
      W5BTOL = W5BTLS
  601 CONTINUE
      RETURN
      END
```

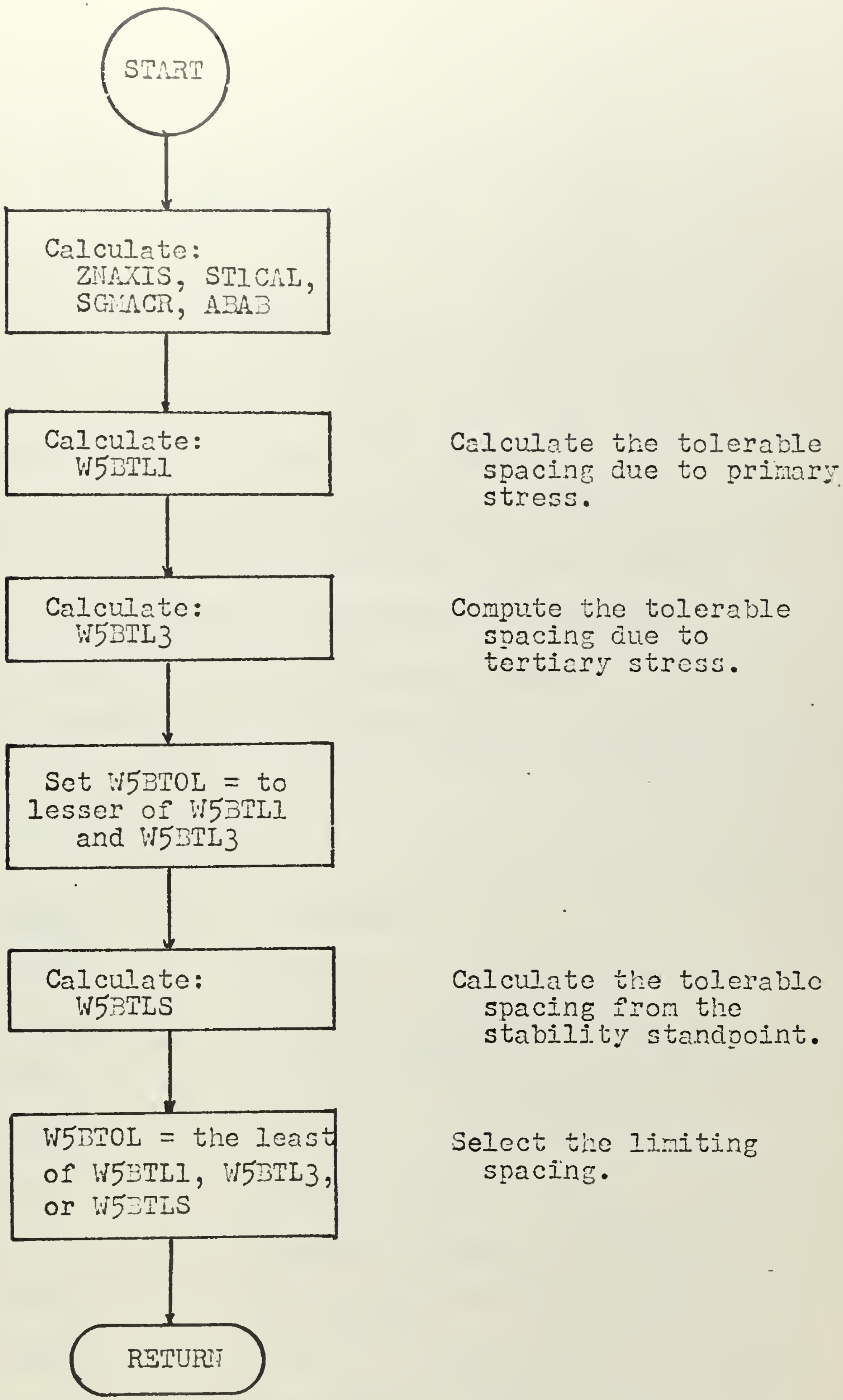


FIGURE VII

SUBROUTINE CSPACE FLOW CHART

F. SUBROUTINE CLONGL

1. DESCRIPTION

Introduction

Subroutine CLONGL is designed to calculate the required section modulus for the longitudinal-plating combination, as well as the minimum permissible radius of gyration. The resulting computation is concerned solely with strength criteria, as the criteria for plating-longitudinal stability are determined later in the main program.

Inputs

Symbol	Meaning
ST1CRK	Maximum permissible stress at keel. (Tons/In.^{2})
ST1CRD	Maximum permissible stress at deck centerline. (Tons/In.^{2})
ST2EST	Estimated value of secondary stress. (Tons/In.^{2})
SGMULT	Yield stress of the plating. (Tons/In.^{2})
FRM	Transverse frame spacing. (Feet)
TH1	Plating thickness. (Inches)
YPTLOC	Half breadth of longitudinal. (Feet)
ZPTLOC	Height of longitudinal above base line. (Feet)
W5BPRC	Span from preceding longitudinal. (Feet)

Symbol	Meaning
R5GYRA	Required radius of gyration of plating-longitudinal combination. (Inches)

Calculated Items

Symbol	Meaning
XR5GYR	Calculated radius of gyration required for given longitudinal location. (Inches)
PRESS	Hydrostatic pressure at longitudinal. (Pounds/In.^{2})
ZNAXIS	Location of neutral axis of DD-931 midship section above base line. (Feet)
ST1CAL	Calculated primary compressive stress at longitudinal. (Feet)
WIDTH	Permissible span for cases where span exceeds 50.0 x TH1. (Inches)
EWIDTH	Effective width of plating, dictated by the lesser of WIDTH and 12.0 x W5BPRC. (Inches)
XMB1LG	Bending moment at mid-span of plating-longitudinal combination. (Inch-Pounds)
ST3LGL	Tolerable level of tertiary stress. (Tons/In.^{2} converted to Lb./In.^{2})

Output

Symbol	Meaning
R5GYRA	Required radius of gyration of plating-longitudinal combination. (Inches)
XMD1MN	Required section modulus of plating-longitudinal combination. (In.^{3})

Calling Sequence

```
Call CLONGL (ST1CRK, ST1CRD, ST2EST, SGMULT, FRM,
             TH1, W5BPRC, R5GYRA, XMD1MN, YPTLOC,
             ZPTLOC)
```

Sample Input/Output (Computer test run)

Input:	ST1CRK	7.93	Tons/In.^{2}
	ST1CRD	6.00	Tons/In.^{2}
	ST2EST	1.34	Tons/In.^{2}
	SGMULT	20.98	Tons/In.^{2}
	FRM	8.00	Feet
	THL	0.28125	Inches
	YPTLOC	1.768	Feet
	ZPTLOC	0.045	Feet
	W5BPRC	1.769	Feet
	R5GYRA	3.097	Inches
Output:	R5GYRA	3.097	Inches
	XMD1MN	8.277	In.^{3}

Fundamental Equations

$$XR5GYR = \frac{12.0 \times FRM}{31.}$$

$$PRESS = 0.445 \times HM$$

$$ZNAXIS = 26.23125 \times \frac{ST1CRK}{ST1CRK + ST1CRD}$$

$$ST1CAL = ST1CRK \times \left|\frac{ZNAXIS - ZPTLOC}{ZNAXIS}\right|$$

$$WIDTH = 50.0 \times THL$$

$$XMB1LG = 18.0 \times PRESS \times EWIDTH \times FRM^2$$

$$ST3LGL = SGMULT - ST1CAL - ST2EST$$

$$ST3LGL = 2240. \times ST3LGL$$

$$XMD1MN = \frac{XMB1LG}{ST3LGL}$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$$XR5GYR = \frac{96.}{31.} = \underline{3.097}$$

$$PRESS = 0.445 \times 30.14$$
$$= \underline{13.4}$$

$$ZNAXIS = 26.23125 \times \frac{7.93}{13.93}$$

$$ST1CAL = 7.93 \times \frac{14.94 - 0.045}{14.94}$$
$$= \underline{7.90}$$

W5BPRC = 21.23 inches

WIDTH = 14.06

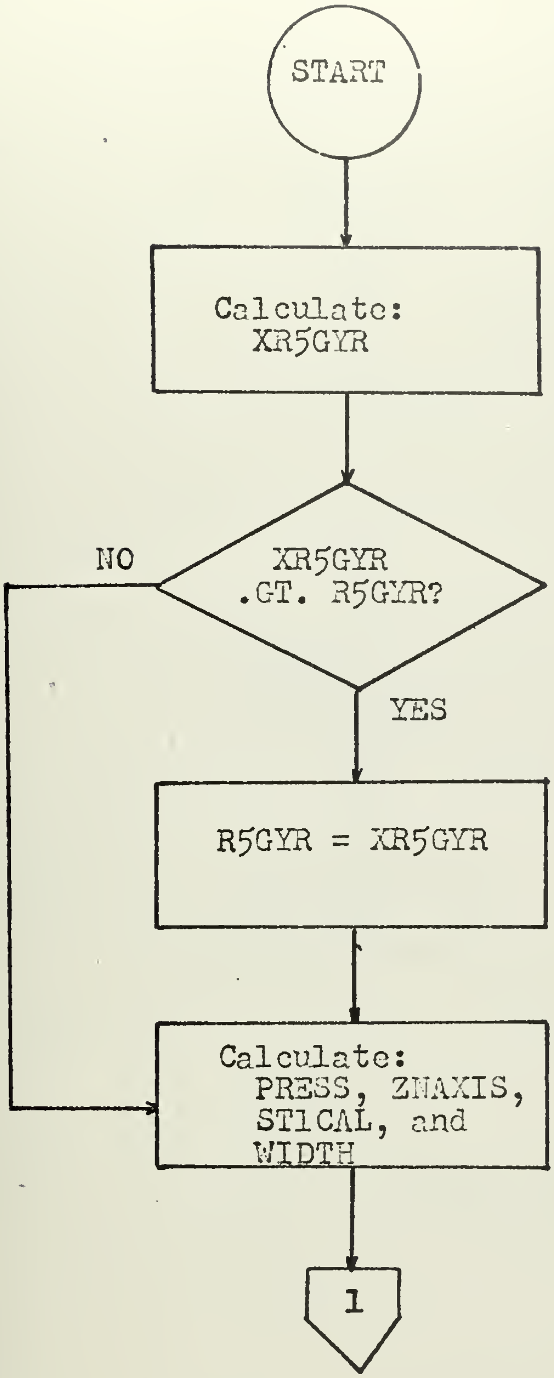
EWIDTH = WIDTH = 14.06

XMB1LG = 18. x 13.4 x 14.06 x 64.
= 217,000

ST3LGL = 26,320 psi

$$XMD1MN = \frac{217,000}{26,320} = 8.28$$

```
      SUBROUTINE CLONGL( ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,W5BPRC,
     1 R5GYRA,XMD1MN,YPTLOC,ZPTLOC)
      XR5GYR = 12.0 * FRM / 31.0
      IF (XR5GYR - R5GYRA) 201, 203, 203
  203 R5GYRA = XR5GYR
  201 A3HEEL = 0.5236
      AAA = W5BPRC
      D1 = 26.231247
      H1AMDK = 4.0
      H1DFL = 14.5
      NBELTS = 1
      XL1BP = 407.
      CALL HDWTR (A3HEEL,YPTLOC,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZPTLOC,HM)
      PRESS = 0.445 * HM
      ZNAXIS = 26.231247 * ST1CRK / (ST1CRK + ST1CRD)
      ST1CAL = ST1CRK * ABS ((ZNAXIS - ZPTLOC)/ZNAXIS)
      W5BPRC = 12.0 * W5BPRC
      WIDTH = 50.0 * TH1
      IF (W5BPRC .LT. WIDTH) GO TO 600
      EWIDTH = WIDTH
      GO TO 601
  600 EWIDTH = W5BPRC
  601 XMB1LG = 18.0 * PRESS * EWIDTH * (FRM**2)
      ST3LGL = SGMULT - ST1CAL - ST2EST
      W5BPRC = AAA
      ST3LGL = 2240. * ST3LGL
      XMD1MN = XMB1LG / ST3LGL
      RETURN
      END
```

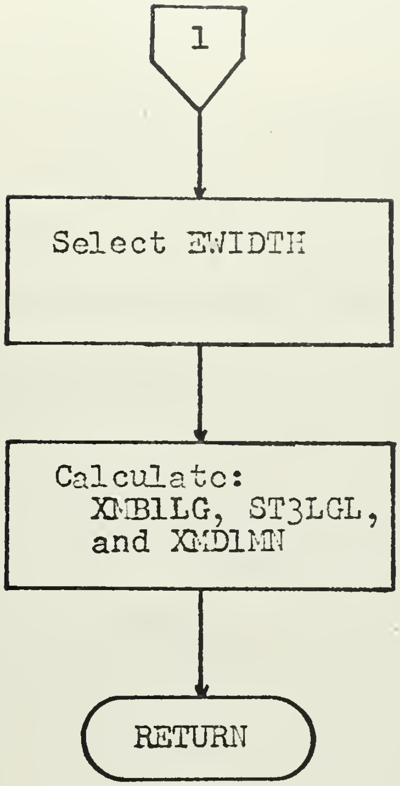


Determine the limiting value of the radius of gyration.

Do the preliminary computations for determining the effective width of plating.

FIGURE VIII

SUBROUTINE CLONGL FLOW CHART



Determine the required section modulus for the plating-longitudinal combination.

FIGURE VIII - Continued

G. SUBROUTINE PMINER

1. DESCRIPTION

Introduction

The characteristic data delineating the contribution of the half breadth plating to the total area and section modulus of the midship section were generated by subroutine WTSMOD for all available plating thicknesses, up to one inch maximum. This information is imbedded in subroutine PMINER in such a way that, given an input of the plating thickness, the appropriate information detailing the effects of the plating on the total area and section modulus is provided.

Inputs

Symbol	Meaning
THL	Plating thickness. (Inches)

Calculated Items

None. Subroutine PMINER merely selects the correct values of BLMOM, AREAPT, XMOMIN, and XINER (defined below) for the given input value of plating thickness.

Output

Symbol	Meaning
BLMOM	Moment about the base line for the half breadth plating. (Inches^2 Feet)
AREAPT	Total area for the half breadth plating. (Inches^2)
XMOMIN	Net moment of inertia about the base line for the half breadth plating. (Inches^2 Feet^2)
XINER	Moment of inertia of the total midship section plating about the neutral axis for the plating. (Inches^2 Feet^2)

Calling Sequence

Call PMINER (TH1, BLMOM, AREAPT, XMOMIN, XINER)

Sample Input/Output (Computer test run)

Input:	TH1	0.625	inches
Output:	BLMOM	6883.683+	inches^2 feet
	AREAPT	472.306+	inches^2
	XMOMIN	153184.375	inches^2 feet^2
	XINER	105714.562+	inches^2 feet^2

Fundamental Equations

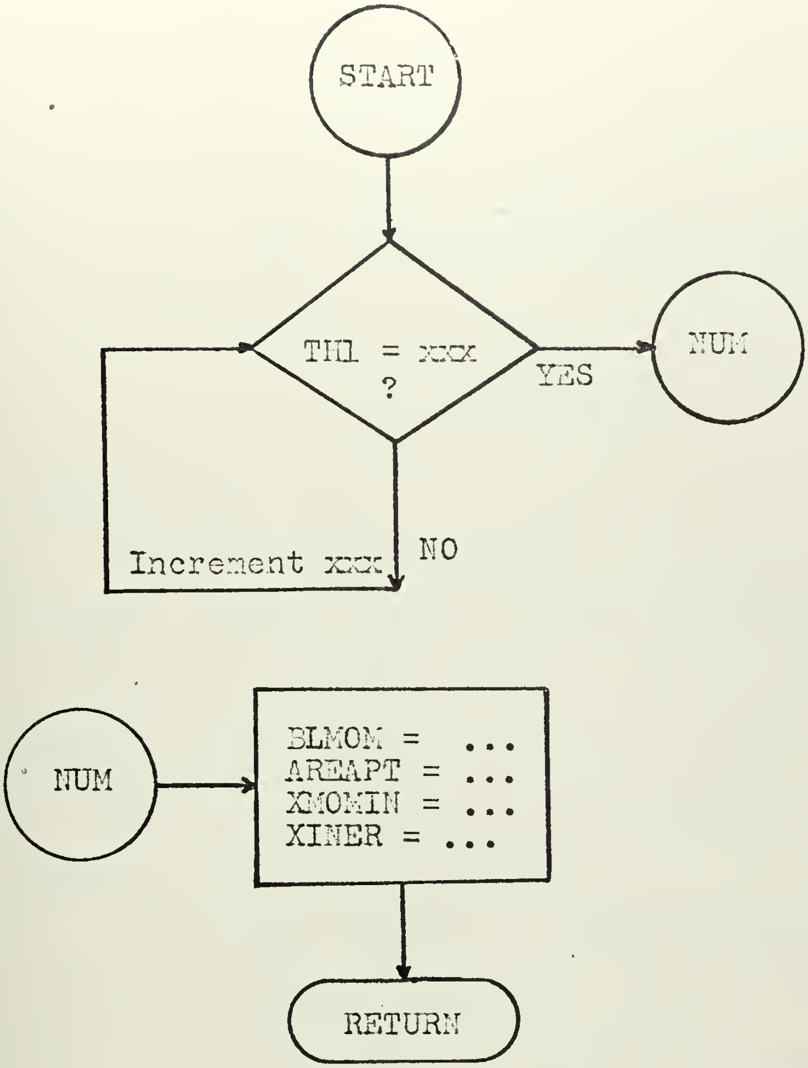
None.

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

None.

```
      SUBROUTINE PMINER (TH1,BLMOM,AREAPT,XMOMIN,XINER)
      IF ((TH1 - 0.25000) .EQ. 0.0) GO TO 17
      IF ((TH1 - 0.28125) .EQ. 0.0) GO TO 18
      IF ((TH1 - 0.31250) .EQ. 0.0) GO TO 19
      IF ((TH1 - 0.34375) .EQ. 0.0) GO TO 20
      IF ((TH1 - 0.37500) .EQ. 0.0) GO TO 21
      IF ((TH1 - 0.43750) .EQ. 0.0) GO TO 22
      IF ((TH1 - 0.50000) .EQ. 0.0) GO TO 23
      IF ((TH1 - 0.62500) .EQ. 0.0) GO TO 24
      IF ((TH1 - 0.75000) .EQ. 0.0) GO TO 25
      IF ((TH1 - 0.87500) .EQ. 0.0) GO TO 26
      IF ((TH1 - 0.93750) .EQ. 0.0) GO TO 27
      IF ((TH1 - 1.00000) .EQ. 0.0) GO TO 28
   17 BLMOM   =  2753.5119629
      AREAPT =    188.9225464
      XMOMIN = 61274.3710937
      XINER   = 42284.8554687
      RETURN
   18 BLMOM   =  3097.7021484
      AREAPT =    212.5378418
      XMOMIN = 68933.5
      XINER   = 47570.0546875
      RETURN
   19 BLMOM =    3441.895752
      AREAPT =    236.1531372
      XMOMIN = 76592.5625
      XINER   = 52854.8671875
      RETURN
   20 BLMOM   =  3786.0852051
      AREAPT =    259.7683105
      XMOMIN = 84251.5625
      XINER =   58139.7304687
      RETURN
   21 BLMOM   =  4130.2734375
      AREAPT =    283.3835449
      XMOMIN = 91910.625
      XINER =   63424.9726562
      RETURN
   22 BLMOM   =  4818.6132812
      AREAPT =    330.6142578
      XMOMIN =107228.8125
      XINER   = 73997.5625
      RETURN
   23 BLMOM   =  5506.96875
      AREAPT =    377.8449707
      XMOMIN =122547.25
      XINER   = 84569.8125
      RETURN
```

```
 24   BLMOM   =  6883.6835937
      AREAPT  =   472.3061523
      XMOMIN =153184.375
      XINER =105714.5625
      RETURN
 25   BLMOM   =  8260.421875
      AREAPT  =   566.7675781
      XMOMIN =183821.125
      XINER   =126857.125
      RETURN
 26   BLMOM   =  9637.1679687
      AREAPT  =   661.2287598
      XMOMIN =214458.25
      XINER   =148000.
      RETURN
 27   BLMOM   = 10325.5351562
      AREAPT  =   708.4592285
      XMOMIN =229777.25
      XINER   =158572.5625
      RETURN
 28   BLMOM   = 11013.9257812
      AREAPT  =   755.6901855
      XMOMIN =245096.0625
      XINER =169143.625
      RETURN
      END
```



(Tabulated values, to be inserted above)

xxx	NUM	BLMOM	AREAPT	XMOMIN	XINER
0.25	17	2753.5+	118.9+	61274.+	42284.+
0.28125	18	3097.7+	212.5+	68933.+	47570.+
0.3125	19	3441.8+	236.1+	76592.+	52854.+
0.34375	20	3786.0+	259.7+	84251.+	58139.+
0.375	21	4130.2+	283.3+	91910.+	63424.+
0.4375	22	4818.6+	330.6+	107228.+	73997.+
0.5	23	5506.9+	377.8+	122547.+	84569.+
0.625	24	6883.6+	472.3+	153184.+	105714.+
0.75	25	8260.4+	566.7+	183821.+	126857.+
0.875	26	9637.1+	661.2+	214458.+	148000.
0.9375	27	10325.5+	708.4+	229777.+	158572.+
1.0	28	11013.9+	755.6+	245096.+	169143.+

FIGURE IX

SUBROUTINE PMINER FLOW CHART

H. SUBORDINATE PROGRAM SHDATA

1. DESCRIPTION

Introduction

Program SHDATA generates input data required for main program RUNSCORE (after further manipulation by subroutine PLTGTH). The midship section molded form of DD-931, originally defined by a series of nineteen cubic equations,* is defined in detail by a mesh of one hundred ninety-one points by subroutine SHDATA.

Each cubic equation, with one coordinate variable defined in terms of the other, is used to generate ten points on the surface of the midship section shell molded form. The final point defines the shell-plating intersection. The output of this subroutine is then used as an input to program PTLGTH, which calculates the distance between adjacent points.

Inputs

Symbol	Meaning
COORD1	The dependent variable. (Y or Z)

---

*Provided by courtesy of Mr. Lee Mount of J. J. Henry Co., Inc.

Symbol	Meaning
COORD2	The independent variable. (Z or Y)
NOSEG	The number of the cubic equation. (From 1 through 19)
PTMIN	Minimum value of the independent variable. (Feet)
PTMAX	Maximum value of the independent variable. (Feet)
AA	Fixed quantity in the cubic equation.
BB	Coefficient of the first power independent variable.
CC	Coefficient of the second power independent variable.
DD	Coefficient of the third power independent variable.

Calculated Items

Symbol	Meaning
VV	The independent variable. (Feet)
SUM	The dependent variable. (Feet)
DIFF	Range of the independent variable. (Feet)

Output

Symbol	Meaning
EE	Half breadth of point. (Feet)
FF	Height of point above base line. (Feet)

Sample Input/Output (Computer test run)

Input:

COORD1	Z	
COORD2	Y	
NOSEG	1	
PTMIN	0.0	Feet
PTMAX	2.0	Feet
AA	0.0000	
BB	0.023692	
CC	0.0000	
DD	0.00058957	

Output:

Segment	Point	Y	Z
1	1	0.00	0.000000
1	2	0.20	0.004743
1	3	0.40	0.009515
1	4	0.60	0.014343
1	5	0.80	0.019255
1	6	1.00	0.024282
1	7	1.20	0.029449
1	8	1.40	0.034787
1	9	1.599999	0.040322
1	10	1.799999	0.046084

<u>Fundamental Equations</u>

SUM = AA + BB x VV + CC x VV^2 + DD x VV^3

VV = VV + STEP

STEP = DIFF / 10.

DIFF = PTMAX - PTMIN

<u>Sample Calculation</u> (Refer to subordinate program listing and flow chart, following pages)

DIFF = PTMAX - PTMIN
= <u>2.0</u>

STEP = 2.0 / 10.
= <u>0.20</u>

VV = <u>0.20</u>

SUM = 0.023692 x VV + 0.00058957 x VV^3
= <u>0.004743</u>

```
          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DE

  ISN 0002          901 FORMAT (2A1,I3,6F10.5)
  ISN 0003          902 FORMAT (1H0,A1,15H A FUNCTION OF ,A1,9H SEGMENT ,I2,7H POI
                      114H X= 205.500000),3H Y=,F10.6,3H Z=, F10.6)
  ISN 0004          903 READ (5,901) COORD1,COORD2,NOSEG,PTMIN,PTMAX,AA,BB,CC,DD
  ISN 0005              DIFF = PTMAX - PTMIN
  ISN 0006              STEP = DIFF / 10.
  ISN 0007              VV = PTMIN
  ISN 0008              DO 907 I = 1, 10
  ISN 0009              SUM = AA & BB*VV & CC*(VV**2) & DD*(VV**3)
  ISN 0010              IF (NOSEG .GT. 7) GO TO 905
  ISN 0012              EE = SUM
  ISN 0013              FF = VV
  ISN 0014              GO TO 906
  ISN 0015          905 EE = VV
  ISN 0016              FF = SUM
  ISN 0017          906 WRITE (6,902) COORD1,COORD2,NOSEG,I,FF,EE
  ISN 0018          904 WRITE (7,902) COORD1,COORD2,NOSEG,I,FF,EE
  ISN 0019          907 VV = VV & STEP
  ISN 0020              IF ((NOSEG - 22) .EQ. 0) GO TO 917
  ISN 0022              GO TO 903
  ISN 0023          917 STOP
  ISN 0024              END
```

}

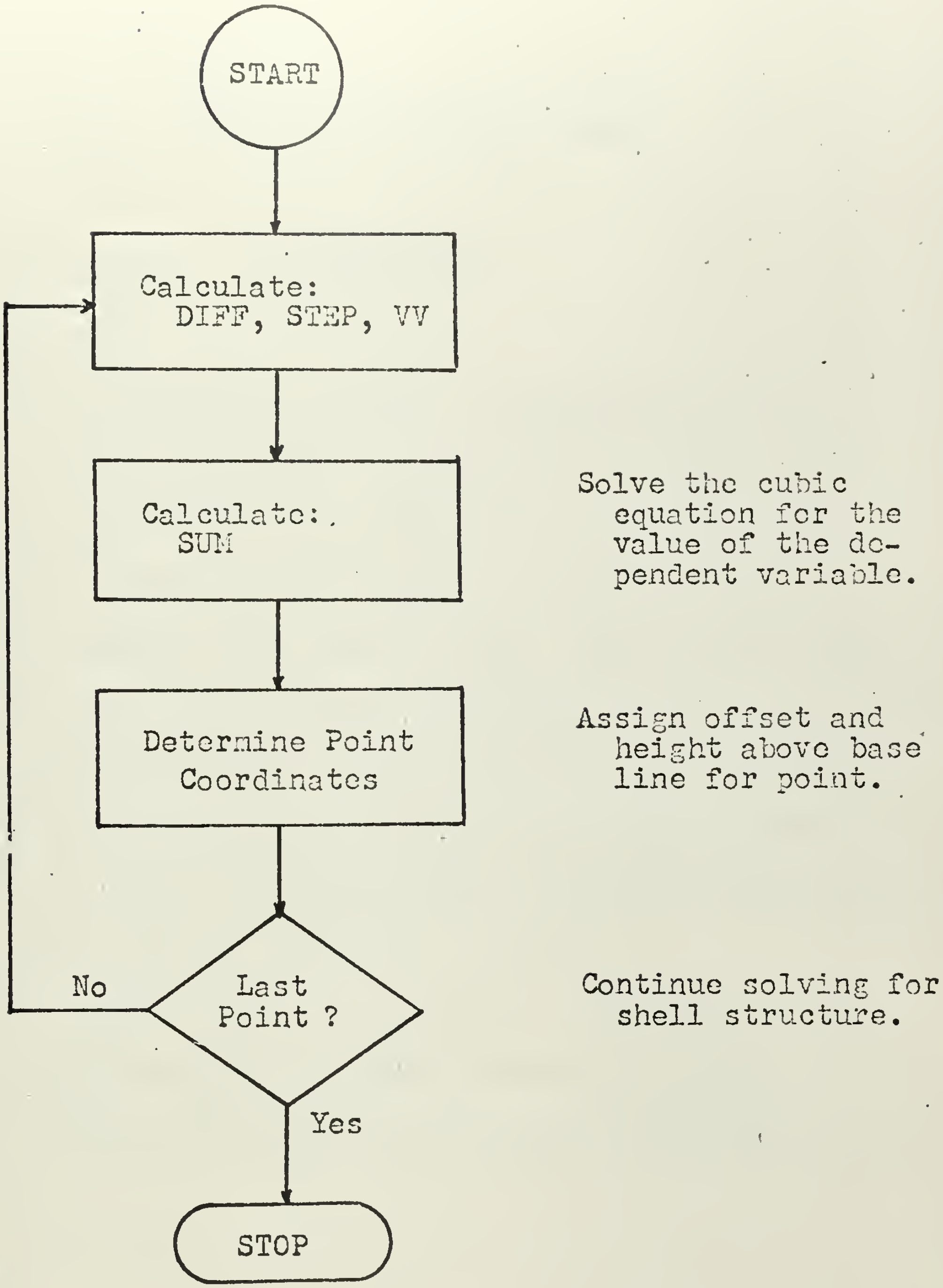


FIGURE X

SUBORDINATE PROGRAM <u>SHDATA</u> FLOW CHART

I. SUBORDINATE PROGRAM DKDATA

1. DESCRIPTION

Introduction

Program DKDATA is designed to generate a series of points on the molded deck of the midship section of DD-931. The half breadths of the points are determined on the basis of the angle of the sine function used to define the height of the camber curve. For the deck edge, the sine equals zero, while the value is one at the centerline. A direct correlation between the angle involved and the half breadth is maintained—if the angle is forty-five degrees, the point defined exists at exactly half the maximum breadth of the molded deck plating.

One hundred points are defined, equivalent to ten cubic segments with ten points evaluated on each, as in program SHDATA. One added point defines the centerline of the deck.

Inputs

Symbol	Meaning
COORD1	The dependent variable. (Z)
COORD2	The independent variable. (Y)
ZMIN	The height of the deck edge above the base line. (Feet)

Symbol	Meaning
ZMAX	The height of the deck centerline above the base line. (Feet)
YMAX	The half breadth of the deck edge. (Feet)

Calculated Items

Symbol	Meaning
STEP	Angular increment for the sine function. (Radians)
YYY	Increment of the halfbreadth for adjacent points. (Feet)
FF/YBEG	Offsets of the point. (Feet)
DIFF	Height difference between the deck edge and the deck centerline. (Feet)
NOSEG	"Segment" number—for uniformity with SHDATA output.
I	"Point" number within the segment.
ANGLE	Angle to be used for the camber calculation of the height of the deck. (Radians)

Output

Symbol	Meaning
FF	Offsets to the point. (Feet)
EE	Height of the point above the base line. (Feet)

Sample Input/Output (Computer test run)

Input:	COORD1	Z	
	COORD2	Y	
	ZMIN	25.239594	Feet
	ZMAX	26.231247	Feet
	YMAX	22.343796	Feet

Output:	Segment	Point	Y	Z
	20	1	22.343796	25.239594
	20	2	22.120346	25.255157
	20	3	21.896896	25.270737
	30	1	-0.000348	26.231247

<u>Fundamental Equations</u>

STEP = THETA / 100.

YYY = YMAX / 100.

YBEG = YMAX, later = YBEG - YYY

DIFF = ZMAX - ZMIN

ANGLE = ANGLE + STEP

EE = ZMIN + DIFF x SIN(ANGLE)

FF = YBEG

<u>Sample Calculation</u> (Refer to subroutine listing and flow chart, following pages)

STEP = <u>0.015708</u>

YYY = <u>0.22343796</u>

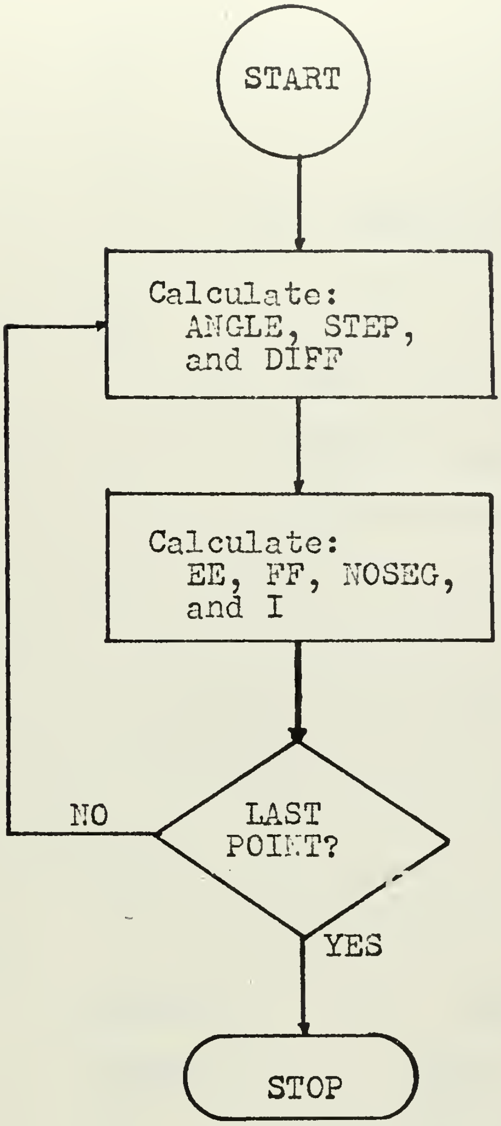
YBEG = <u>22.343796</u>

DIFF = <u>0.991653</u>

EE = 25.239594 + 0.991653 x Sin (0.)
= <u>25.239594</u>

FF = <u>22.343796</u>

```
      COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DE
ISN 0002          901 FORMAT (2A1,3F10.6)
ISN 0003          902 FORMAT (1H0,A1,15H A FUNCTION OF , A1,9H SEGMENT ,I2,7H PO
                     114H X= 203.500000,3H Y=,F10.6,3H Z=, F10.6)
ISN 0004          903 READ (5,901) COORD1, COORD2, ZMIN , ZMAX, YMAX
ISN 0005              THETA = 0.5 * 3.1415927
ISN 0006              STEP = THETA / 100.
ISN 0007              FF = 0.0
ISN 0008              DIFF = ZMAX - ZMIN
ISN 0009              ANGLE = 0.0
ISN 0010              YYY = YMAX / 100.
ISN 0011              YBEG = YMAX
ISN 0012              AA = 0.05
ISN 0013              DO 907 J = 1, 101
ISN 0014              FF = YBEG
ISN 0015              EE = ZMIN & DIFF * SIN(ANGLE)
ISN 0016              NOSEG = AA
ISN 0017              K = AA
ISN 0018              AK = K
ISN 0019              I = 10.0 * (AA & 0.1) - 10.0 * AK
ISN 0020              IF (I .EQ. 0) GO TO 910
ISN 0022              GO TO 909
ISN 0023          910 I = 10
ISN 0024          909 AA = AA & 0.1
ISN 0025              NOSEG = NOSEG & 20
ISN 0026          904 WRITE (6,902) COORD1, COORD2, NOSEG, I, FF, EE
ISN 0027          905 WRITE (7,902) COORD1, COORD2, NOSEG, I, FF, EE
ISN 0028              YBEG = YBEG - YYY
ISN 0029          907 ANGLE = ANGLE & STEP
ISN 0030              STOP
ISN 0031              END
```



Determine the initial angle and the increments of the angles and offsets.

Determine the point coordinates.

FIGURE XI

SUBORDINATE PROGRAM DKDATA FLOW CHART

J. SUBORDINATE PROGRAM PTLGTH

1. DESCRIPTION

Introduction

Program PTLGTH uses the outputs of SHDATA and DKDATA to calculate the distance between adjacent points, based on the assumption that the distance between two points can be closely approximated by a straight line segment. In view of the short distances involved, this results in a relatively precise calculation. The center of gravity of the short segment so defined is evaluated by linear interpolation.

Inputs

Symbol	Meaning
NOSEG1	Segment number of initial point.
I1	Point number of initial point.
YPT1	Half breadth of initial point. (Feet)
ZPT1	Height of initial point above base line. (Feet)
NOSEG2	Segment number of next point.
I2	Point number of next point.
YPT2	Half breadth of next point. (Feet)
ZPT2	Height of next point above base line. (Feet)

Output

Symbol	Meaning
DIST	Distance from initial to next point. (Feet)
ZCGPT	Height of mid point of DIST above base line. (Feet)

Sample Input/Output (Computer test run)

Input:	NOSEG1	1	
	I1	1	
	YPT1	0.0	Feet
	ZPT1	0.0	Feet
	NOSEG2	1	
	I2	2	
	YPT2	0.200000	Feet
	ZPT2	0.004743	Feet
Output:	DIST	0.200056	Feet
	ZCGPT	0.002371	Feet

Fundamental Equations

$$\text{DIST} = \sqrt{(\text{YPT2} - \text{YPT1})^2 + (\text{ZPT2} - \text{ZPT1})^2}$$

$$\text{ZCGPT} = 0.5 \times (\text{ZPT1} + \text{ZPT2})$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$$\text{DIST} = \sqrt{(0.20000)^2 + (0.004743)^2}$$

$$= \underline{0.200056}$$

$$\text{ZCGPT} = 0.5 \times (0.004743)$$

$$= \underline{0.002371}$$

```
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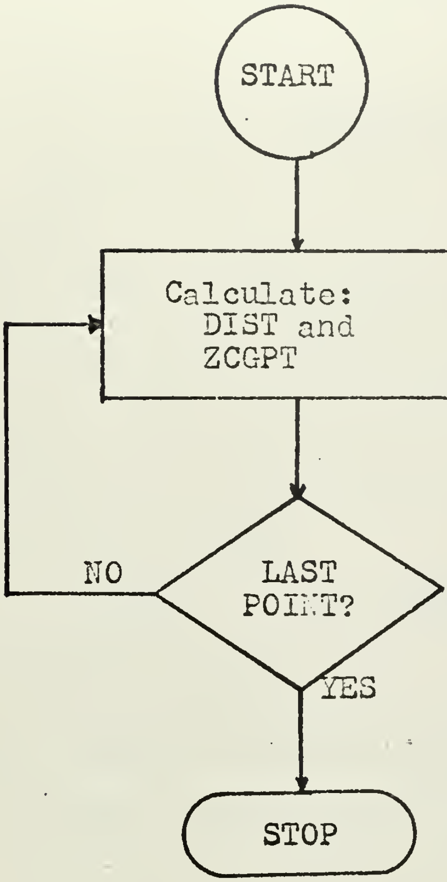
          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,

  ISN 0002        901 FORMAT (27X,I2,7X,I2,17X,F10.6,3X,F10.6)
  ISN 0003            READ (5,901) NOSEG1, I1, YPT1, ZPT1
  ISN 0004        902 READ (5, 901) NOSEG2, I2, YPT2, ZPT2
  ISN 0005            DIST = SQRT ((YPT2 - YPT1)**2 & (ZPT2 - ZPT1)**2)
  ISN 0006            ZCGPT = 0.5 * (ZPT1 & ZPT2)
  ISN 0007        904 FORMAT (1H0, 9H SEGMENT ,I2,9H    POINT , I2, 4(2X,F10.6))
  ISN 0008            WRITE (6,904) NOSEG1,I1,YPT1,ZPT1,DIST,ZCGPT
  ISN 0009            WRITE (7,904) NOSEG1,I1,YPT1,ZPT1,DIST,ZCGPT
  ISN 0010            IF ((NOSEG2 - 30) .EQ. 0) GO TO 911
  ISN 0012            NOSEG1 =NOSEG2
  ISN 0013            I1 = I2
  ISN 0014            YPT1 = YPT2
  ISN 0015            ZPT1 = ZPT2
  ISN 0016            GO TO 902
  ISN 0017        911 DIST = 0.0
  ISN 0018            WRITE (6,904) NOSEG2,I2,YPT2,ZPT2,DIST,ZPT2
  ISN 0019            WRITE (7,904) NOSEG2,I2,YPT2,ZPT2,DIST,ZPT2
  ISN 0020            STOP
  ISN 0021            END
```



Determine the distance between two points and the height of the mid-point above the base line.

FIGURE XII

SUBORDINATE PROGRAM PTLGTH FLOW CHART

K. SUBORDINATE PROGRAM WTSMOD

1. DESCRIPTION

Introduction

Subordinate program WTSMOD calculates the total girth, plating weight, moment of inertia, and location of the neutral axis for the midship section plating. The calculation of the section modulus is based on the following equation: [2]

$$XMDIZ = 2.0 \times \frac{BLMOM^2 - (AREAPT \times XMOMIN)}{BLMOM - AREAPT \times ZCOORD}$$

The output of PTLGTH is used as an input to WTSMOD. Each small segment between points on the girth is treated as a rectangular segment with a width equal to the specified thickness of the plating. The component values used in the calculation of the section modulus are stored in Subroutine PMINER for eventual use in Main Program RUN-SCORE.

Inputs

Symbol	Meaning
PTDATA(I,J,1)	Half-breadth of point (I,J). (Feet)
PTDATA(I,J,2)	Height of point (I,J) above base line. (Feet)
PTDATA(I,J,3)	Distance from point (I,J) to next point. (Feet)

Symbol	Meaning
PTDATA(I,J,4)	Height of midpoint of PTDATA (I,J,3) above base line. (Feet)
WPERIN	Weight of the structural material. (Pounds per inch thickness of a one square foot plate)
TH1	Plating thickness. (Inches)

Calculated Items

Symbol	Meaning
GIRTH	Total distance between points for the half breadth. (Feet)
AA	Intermediate value used in calculating XMOMIN.
BB	Intermediate value used in calculating XMOMIN.

Output

Symbol	Meaning
WTPRFT	Total weight of the plating. (Pounds or Tons per foot)
GIRX2	Total circumference of the midship section plating. (Feet)
BLMOM	Moment of the plating about the base line. (In.^{2} Feet)
AREAPT	Cross-sectional area of the plating. (In.^{2})
XMOMIN	Moment of inertia of the plating about the base line. (In.^{2} Ft.^{2})
XMD1K	Section modulus at the keel. (In.^{2} Feet)
XMD1D	Section modulus at the deck. (In.^{2} Feet)
ZNAX	Height of the center of gravity of the plating above the base line. (Feet)
XINER	Moment of inertia of the plating about ZNAX. (In.^{2} Ft.^{2})

Sample Input/Output (Computer test run)

Input:

		PTDATA(I,J,1)	PTDATA(I,J,2)	PTDATA(I,J,3)
I=1	J=1	0.0	0.0	5.0
	2	3.0	4.0	5.0
	3	6.0	8.0	5.0
	4	9.0	12.0	5.0
	5	12.0	16.0	0.0

PTDATA(1,1,4)	2.0	Feet
PTDATA(1,2,4)	6.0	Feet
PTDATA(1,3,4)	10.0	Feet
PTDATA(1,4,4)	14.0	Feet
PTDATA(1,5,4)	0.0	Feet
WPERIN	40.8	Pounds per in. per sq. ft.
TH1	0.25	Inches

Output:

WTPRFT	408.0	Pounds per foot
GIRX2	40.0	Feet
BLMOM	480.0	In.^{2} Ft.
AREAPT	60.0	In.^{2}
XMOMIN	5120.0	In.^{2} Ft.^{2}
XMD1K	320.0	In.^{2} Ft.
XMD1D	140.42	In.^{2} Ft.
ZNAX	8.0	Feet
XINER	2560.0	In.^{2} Ft.^{2}

Fundamental Equations

$$\text{GIRTH} = \text{GIRTH} + \text{PTDATA(I,J,3)}$$

$$\text{WTPRFT} = 2.0 \times \text{GIRTH} \times \text{WPERIN} \times \text{TH1}$$

$$\text{GIRX2} = 2.0 \times \text{GIRTH}$$

$$\text{AA} = 0.08333 \times \text{TH1} \times \text{PTDATA(I,J,3)}$$

$$\text{BB} = \text{TH1}^2 \times \left(\frac{\text{PTDATA(I+1,1,1,)} - \text{PTDATA(I,J,1)}}{\text{PTDATA(I,J,3)}}\right)^2 + 144. \times (\text{PTDATA(I+1,1,2)} - \text{PTDATA(I,J,2)})^2$$

$$\text{BLMOM} = \text{BLMOM} + 12. \times \text{TH1} \times \text{PTDATA(I,J,3)} \times \text{PTDATA(I,J,4)}$$

$$\text{AREAPT} = 12. \times \text{GIRTH} \times \text{TH1}$$

$$\text{XMOMIN} = \text{XMOMIN} + 0.0833 \times \text{AA} \times \text{BB} + 12. \times \text{TH1} \times \text{PTDATA(I,J,3)} \times \text{PTDATA(I,J,4)}^2$$

$$\text{XMD1K} = 2.0 \times \left(\frac{\text{BLMOM}^2 - \text{AREAPT} \times \text{XMOMIN}}{\text{BLMOM}}\right)$$

$$XMD1D = 2.0 \times \frac{BLMOM^2 - AREAPT \times XMOMIN}{BLMOM - 26.23125 \times AREAPT}$$

$$ZNAX = \frac{BLMOM}{AREAPT}$$

$$XINER = XMD1K \times ZNAX$$

<u>Sample</u> <u>Calculation</u> (Refer to subroutine listing and flow chart, following pages)

$$XINER = \frac{1}{12} \times \frac{1}{4} \times 20 \times \left[\frac{1}{192} \times \left(\frac{3}{5}\right)^2 + 4800 \times \left(\frac{4}{5}\right)^2\right]$$

$$= \underline{2,560} \text{ in.}^2 \text{ ft.}^2$$

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COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DECK,LOAD,M

```
      DIMENSION PTDATA (30,10,4)
  900 FORMAT (2F20.7)
  901 FORMAT (23X,4(2X,F10.6))
      DO 907 I = 1, 29
      DO 907 J=1, 10
      READ (5, 901) PTDATA (I,J,1),PTDATA(I,J,2),PTDATA(I,J,3),
     1 PTDATA(I,J,4)
  907 CONTINUE
      I = 30
      J = 1
      READ (5, 901) PTDATA(I,J,1),PTDATA(I,J,2),PTDATA(I,J,3),
     1 PTDATA(I,J,4)
      DO 910 J = 2, 10
      DO 910 K = 1, 4
  910 PTDATA (I,J,K) = 0.0
  888 READ (5,900) WPERIN, TH1
      IF ((WPERIN - 100.) .GT. 0) GO TO 999
   84 FORMAT ('1  PLATING THICKNESS =',F10.6,' INCHES')
   85 FORMAT ('    WEIGHT =',F10.6,' POUNDS PER SQ. FT. PER INCH THICKNES
     1S')
      WRITE (6, 84) TH1
      GIRTH = 0.0
      DO 800 I = 1, 30
      DO 800 J = 1, 10
  800 GIRTH = GIRTH & PTDATA(I,J,3)
      WTPRFT = 2.0 * GIRTH * WPERIN * TH1
  801 FORMAT ('0 PLATING WEIGHT =',F20.7,' POUNDS PER FOOT')
  802 FORMAT ('  PLATING WEIGHT =',F20.7,' TONS PER FOOT')
  803 FORMAT ('0 TOTAL MIDSHIP SECTION GIRTH =',F15.7,' FEET')
      GIRX2 = 2.0 * GIRTH
      WRITE (6,803) GIRX2
      WRITE (6,801) WTPRFT
      WTPRFT = WTPRFT / 2240.
      WRITE (6, 802) WTPRFT
      WRITE (6,85) WPERIN
      BLMOM = 0.0
      AREAPT = GIRTH * TH1 * 12.0
      DO 400 I = 1, 29
      DO 400 J = 1, 10
  400 BLMOM = BLMOM & 12. * TH1 * PTDATA(I,J,3) * PTDATA (I,J,4)
      XMOMIN = 0.0
      DO 500 I = 1, 29
      DO 500 J = 1, 10
      AA = 0.083333 * TH1 * PTDATA (I,J,3)
      IF ((J - 10) .NE. 0) GO TO 501
      BB = (TH1**2)*((PTDATA(I&1,1,1)-PTDATA(I,J,1))/PTDATA(I,J,3))**2 &
     1 ((PTDATA(I&1,1,2) - PTDATA(I,J,2))**2) * 144.
      GO TO 600
  501 BB = (TH1**2)*((PTDATA(I,J&1,1) - PTDATA(I,J,1))/PTDATA(I,J,3))**2
```

```
     1 & 144. * (PTDATA(I,J&1,2) - PTDATA(I,J,2))**2
 600 XMOMIN = 0.08333*AA*BB & XMOMIN & 12.* PTDATA(I,J,3)*TH1*PTDATA
    1(I,J,4)**2
 500 CONTINUE
     XMD1K = 2.0 * (((BLMOM**2) - (AREAPT * XMOMIN)) / BLMOM)
     XMD1D = (((BLMOM**2) - (AREAPT*XMOMIN)) /(BLMOM - 26.231247
    1 * AREAPT)) * 2.0
 304 FORMAT ('0  SECTION MODULUS--KEEL =',F20.7,' INCHES**2  FEET')
 305 FORMAT ('0  SECTION MODULUS--DECK =',F20.7,'  INCHES**2 FEET')
 307 FORMAT ('0  MOMENT OF INERTIA IS',F20.7,' INCHES**2  FEET**2')
     ZNAX = BLMOM / AREAPT
     XINER = XMD1K * ZNAX
     WRITE (6,307) XINER
 306 FORMAT ('0  NEUTRAL AXIS IS',F20.7,' FEET ABOVE BASE LINE')
 401 FORMAT ('0  BLMOM =',F20.7,' FT  IN**2')
 402 FORMAT ('0 AREAPT =',F20.7,' IN**2')
 403 FORMAT ('0 XMOMIN =',F20.7,' FT**2  IN**2')
     WRITE (6,401) BLMOM
     WRITE (6,402) AREAPT
     WRITE (6,403) XMOMIN
     WRITE (6,306) ZNAX
     WRITE (6, 304) XMD1K
     WRITE (6, 305) XMD1D
     GO TO 888
 999 STOP
     END
```

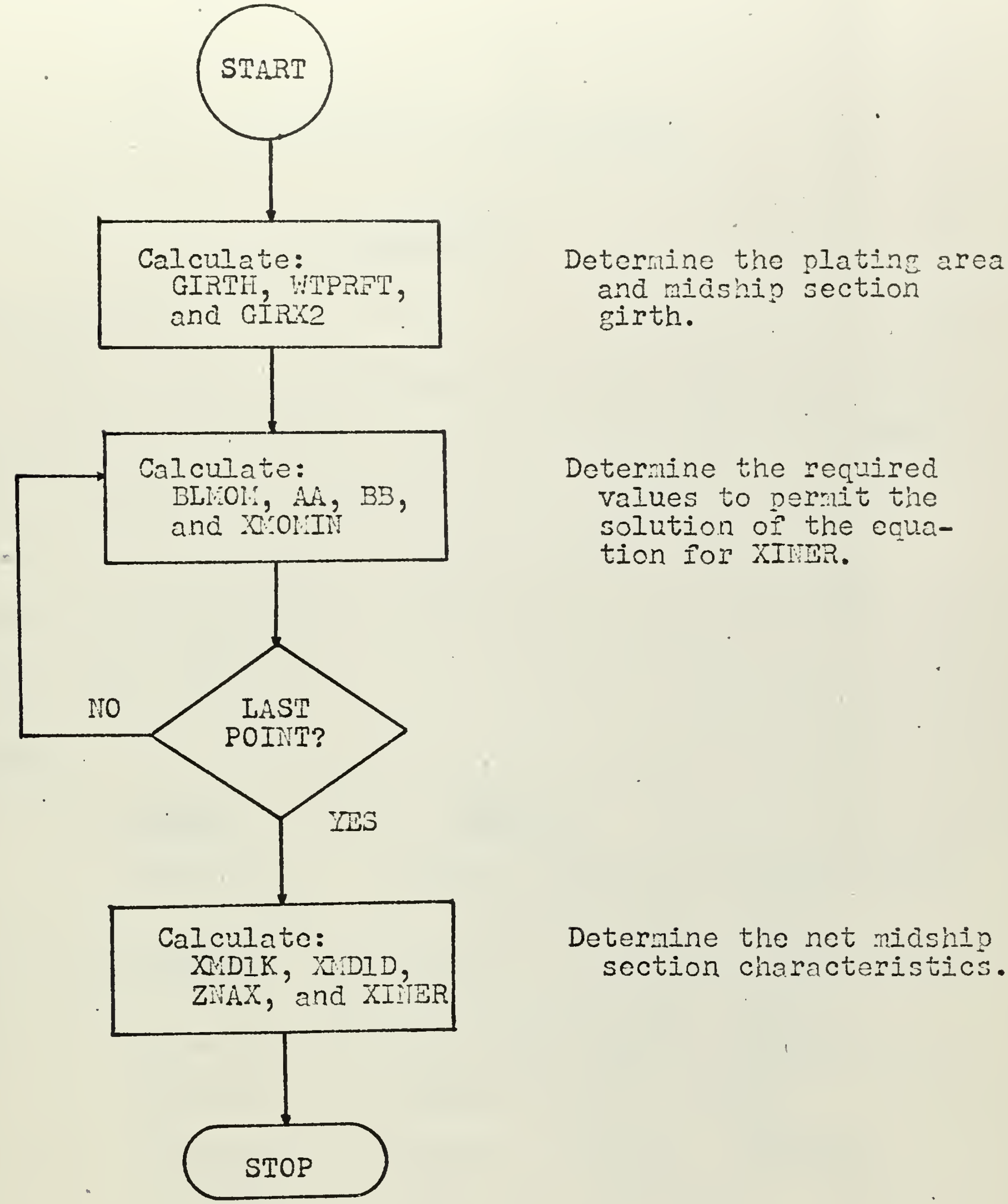

FIGURE XIII

SUBORDINATE PROGRAM WTSMOD FLOW CHART

L. SUBORDINATE PROGRAM TSHAPE

1. DESCRIPTION

Introduction

Subordinate program TSHAPE calculates the structural characteristics of wide flange sections cut to a T-section. For the purposes of calculating the maximum and minimum moments of inertia and the cross-sectional area, it is assumed that the flange is cut off at a distance 0.125 inches from the web.

Inputs

Symbol	Meaning
SMAXI(I)	Maximum moment of inertia of the original member, about its neutral axis. ($In.^4$)
SMINI(I)	Minimum moment of inertia of the original member, about its neutral axis. ($In.^4$)
SAREA(I)	Cross-sectional area of the original member. ($In.^2$)
SFLGW(I)	Flange width. (Inches)
SFLGTH(I)	Flange thickness. (Inches)
SDEPTH(I)	Web depth. (Inches)
SWEBTH(I)	Web thickness. (Inches)
SCOST(I)	Acquisition cost. (Dollars/Foot length)

Calculated Items

Symbol	Meaning
SM	Moment of the cut member about the cut flange. ($In.^3$)
SA	Cross-sectional area of the cut member. ($In.^2$)
SI	Moment of inertia of the cut member about the cut flange. ($In.^4$)
SMAXI(I)	Maximum moment of inertia of the cut member, about its neutral axis. ($In.^4$)
SMINI(I)	Minimum moment of inertia of the cut member, about its neutral axis. ($In.^4$)
SAREA(I)	Cross-sectional area of the cut member. ($In.^2$)
SFLGW(I)	Flange width. (Inches)
SFLGTH(I)	Flange thickness. (Inches)
SDEPTH(I)	Web depth. (Inches)
SWEBTH(I)	Web thickness. (Inches)
SCOST(I)	Acquisition cost. (Dollars/Foot length)
VCG(I)	Distance of the neutral axis from the cut flange. (Inches)

Sample Input/Output (Computer test run)

Input:	SMAXI(1)	21.70	$In.^4$
	SMINI(1)	2.89	$In.^4$
	SAREA(1)	3.53	$In.^2$
	SFLGW(1)	4.00	In.
	SFLGTH(1)	0.279	In.
	SDEPTH(1)	6.00	In.
	SWEBTH(1)	0.23	In.
	SCOST(1)	2.00	Dollars/Foot
Output:	SMAXI(1)	10.56	$In.^4$
	SMINI(1)	1.40	$In.^4$
	SAREA(1)	2.55	$In.^2$
	SFLGW(1)	4.00	In.
	SFLGTH(1)	0.279	In.
	SDEPTH(1)	6.00	In.
	SWEBTH(1)	0.23	In.
	SCOST(1)	2.00	Dollars/Foot
	VCG(1)	4.10	In.

Fundamental Equations

$$VCG(I) = \left[\frac{0.5 \times SDEPTH(I) \times SAREA(I) - 0.5 \times SFLGTH(I)^2 \times (SFLGW(I) - .25 - SWEBTH(I))}{SAREA(I) - SFLGTH(I) \times (SFLGW(I) - .25 - SWEBTH(I))} \right]$$

$$SM = 0.5 \times SDEPTH(I) \times SAREA(I) - 0.5 \times SFLGTH(I)^2 \times (SFLGW(I) - .25 - SWEBTH(I))$$

$$SA = SAREA(I) - SFLGTH(I) \times (SFLGW(I) - .25 - SWEBTH(I))$$

$$SI = SMAXI(I) + SAREA(I) \times (0.5 \times SDEPTH(I))^2 - 0.0833 \times (SFLGW(I) - .25 - SWEBTH(I)) \times SFLGTH(I)^3 - (SAREA(I) - SA) \times (0.5 \times SFLGTH(I))^2$$

$$SMAXI(I) = \frac{VCG(I) \times ((SA \times SI) - SM^2)}{SM}$$

$$SMINI(I) = SMINI(I) - 0.1667 \times SFLGTH(I) \times (0.5 \times (SFLGW(I) - .25 - SWEBTH(I)))^3 - (SAREA(I) - SA) \times (0.125 + 0.5 \times SWEBTH(I) + 0.25 \times (SFLGW(I) - .25 - SWEBTH(I)))^2.$$

$$SAREA(I) = SAREA(I) - SFLGTH(I) \times (SFLGW(I) - .25 - SWEBTH(I))$$

Sample Calculation (Refer to subordinate program listing and flow chart, following pages)

$$VCG(1) = \frac{0.5 \times 6. \times 3.53 - 0.5 \times .279^2 \times 3.52}{3.53 - 0.279 \times 3.52}$$
$$= \underline{4.10}$$

$$SMAXI(1) = 21.70 - 0.1667 \times 1.76 \times 0.279^3 - (0.279 \times 3.52) \times (3.0 - 0.1395)^2$$
$$= \underline{10.56}$$

$$SMINI(I) = 2.89 - 0.1667 \times 0.279 \times 1.76^3 - (0.279 \times 3.52) \times 1.12^2$$
$$= \underline{1.40}$$

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COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DECK,LOAD
      DIMENSION SMAXI(9),SMINI(9),SAREA(9),SFLGW(9),SFLGTH(9),SDEPTH(9)
     1 SWEBTH(9),VCG(9),SCOST(9)
  400 FORMAT (8F10.5)
  401 FORMAT (1H1,3X,'MAX. INERTIA',3X,'MIN. INERTIA',7X,'AREA',7X,
     1 'FLANGE WIDTH', 4X,'THICKNESS',6X,'WEB DEPTH',6X,'THICKNESS',
     2 9X,'COST')
  402 FORMAT (1X,2(3X,'     IN**4    '),4X,'SQ. INCHES',7X,'INCHES',
     1 3(9X,'INCHES'),7X,'DOLLARS/FT.')
      WRITE (6,401)
      WRITE (6,402)
      DO 403 I=1,9
      READ (5,400) SMAXI(I),SMINI(I),SAREA(I),SFLGW(I),SFLGTH(I),SDEPTH
     1 (I),SWEBTH(I),SCOST(I)
  403 CONTINUE
  404 FORMAT (1H0,4X,F10.5,7(5X,F10.5))
      DO 405 I=1,9
      WRITE (6,404) SMAXI(I),SMINI(I),SAREA(I),SFLGW(I),SFLGTH(I),
     1 SDEPTH(I),SWEBTH(I),SCOST(I)
  405 CONTINUE
      DO 406 I = 1,9
      VCG(I) = ((0.5 * SDEPTH(I) * SAREA(I)) - (0.5 * (SFLGTH(I)**2) *
     1(SFLGW(I)-0.25-SWEBTH(I))))/(SAREA(I)-((SFLGW(I)-0.25-SWEBTH(I))*
     2 SFLGTH(I)))
      SA = SAREA(I)*(0.5*SDEPTH(I))-0.5*(SFLGTH(I)**2)*(SFLGW(I)-0.25-
     1 SWEBTH(I))
      SA = SAREA(I) - (SFLGW(I) - 0.25 - SWEBTH(I))*SFLGTH(I)
      SI = SMAXI(I) & SAREA(I)*(0.5*SDEPTH(I))**2 - 0.08333*(SFLGW(I) -
     1 0.25 - SWEBTH(I))*(SFLGTH(I)**3)-(SAREA(I)-SA)*(0.5 * SFLGTH(I))
     2 **2
      SMAXI(I) = VCG(I) * (((SA * SI) - (SM**2)) / SM )
      SMINI(I) = SMINI(I) - 0.16667*SFLGTH(I) * (0.5 * (SFLGW(I) - 0.25-
     1 SWEBTH(I)))**3 - (SAREA(I) - SA) * (0.1258 0.5*SWEBTH(I) & 0.25 *
     2 (SFLGW(I) - 0.25 - SWEBTH(I)))**2
      SAREA(I) = SAREA(I) - (SFLGW(I) - 0.25 -SWEBTH(I)) * SFLGTH(I)
  406 CONTINUE
      WRITE (6,401)
      WRITE (6,402)
  411 FORMAT (15X,'  SHAPE VCG IS ',E10.7,' INCHES FROM EDGE OF CUT FLAN
     1GE')
      DO 407 I=1,9
      WRITE (6,404) SMAXI(I),SMINI(I),SAREA(I),SFLGW(I),SFLGTH(I),
     1 SDEPTH(I),SWEBTH(I),SCOST(I)
      WRITE (6,411) VCG(I)
  407 CONTINUE
      STOP
      END
```
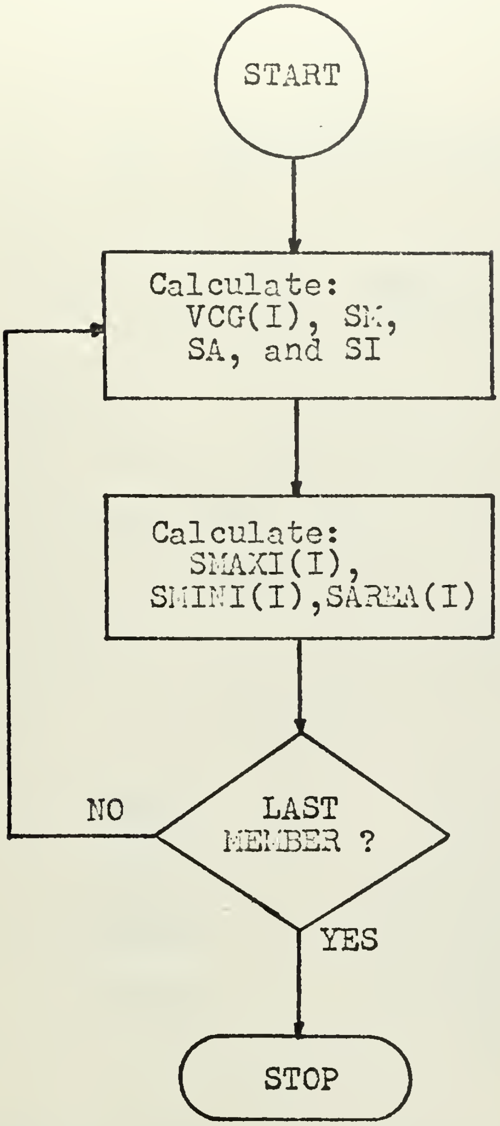



Determine the cut shape VCG and preliminary values for computing SMAXI(I).

Determine the net cut section area and moments of inertia.

FIGURE XIV

SUBORDINATE PROGRAM TSHAPE FLOW CHART

M. SUBORDINATE SUBROUTINE COSTKL

1. DESCRIPTION

Introduction

Subordinate subroutine COSTKL is used to generate the total cost per foot length of the keel structure. The methodology and values used are explained at length in the description of main program COSTDATA.

Inputs

Symbol	Meaning
CKLGTL	Acquisition cost of the keel longitudinal. (Dollars/Foot)
CHCMNH	The cost of one man-hour of work. (Dollars)
FKTHCK	Thickness of the flanges of the keel longitudinal. (Inches)

Calculated Items

Symbol	Meaning
CCUTF	Cost of cutting the keel flanges. (Dollars/Foot)
CWELD	Cost of welding the keel. (Dollars/Foot)

Output

Symbol	Meaning
CKEEL	Total cost of the keel structure. (Dollars/Foot)

<u>Sample Input/Output</u> (Computer test run)

Input:	CKLGTL	9.00	Dollars/Foot
	CHGMNH	7.50	Dollars/Hour
	FKTHCK	0.468	Inches
Output:	CKEEL	27.56	Dollars/Foot

<u>Fundamental Equations</u>

CCUTF = 0.2 x CHGMNH

CWELD = 2.2748 x CHGMNH

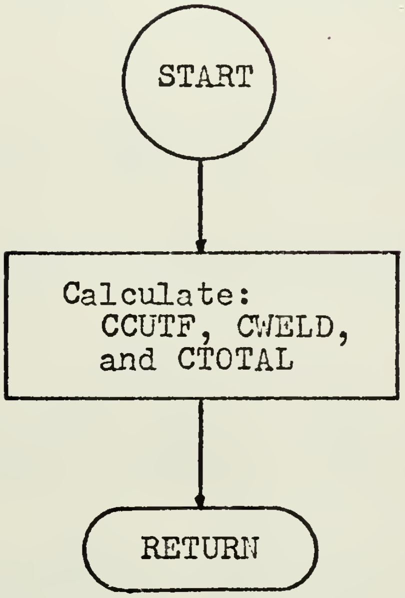
<u>Sample Calculation</u> (Refer to program listing and flow chart, following pages)

CCUTF = <u>1.50</u>

CWELD = <u>17.06</u>

CKEEL = <u>27.56</u>

```
  777 FORMAT (3F20.6)
      READ (5,777) CKLGTL, FKTHCK, CHGMNH
      CALL COSTKL (CKLGTL, FKTHCK, CHGMNH, CKEEL)
  778 FORMAT ('1     ACQUISITION COST =', F10.6)
  779 FORMAT ('0  CHARGE PER MANHOUR =', F10.6)
  780 FORMAT ('0      TOTAL KEEL COST =',F10.6)
      WRITE (6,778) CKLGTL
      WRITE (6,779) CHGMNH
      WRITE (6,780) CKEEL
      STOP
      END
      SUBROUTINE COSTKL (CKLGTL,FKTHCK,CHGMNH,CKEEL)
C
C     CALCULATE THE TOTAL COST CONTRIBUTION OF THE KEEL STRUCTURE.
C
C     FIRST, CALCULATE THE COST OF CUTTING THE FLANGES.
C
      CCUTF = 0.2 * CHGMNH
C
C     CALCULATE THE COST OF WELDING THE SHAPE TO THE PLATING.
C
      CWELD = 2.2748 * CHGMNH
C
C     THE MAN HOUR CHARGES ALLOW FOR MAKE READY AND PUT AWAY, THE WELDING
C     ITSELF, THE CONTINUOUS JOB ALLOWANCE, WIRE BRUSHING, ARC AIR, DYE
C     PENETRANT, AND STRIP HEATER.
C
C     CALCULATE THE TOTAL COST--ACQUISITION, PREPARATION, AND INSTALLATION.
C
      CKEEL = CKLGTL + CCUTF + CWELD
      RETURN
      END
/*
//G.SYSIN DD   *
        9.00                 0.775                7.50
```



Determine the cost of the keel member, per foot length.

FIGURE XV

SUBORDINATE SUBROUTINE <u>COSTKL</u> FLOW CHART

REFERENCE LIST

1. St. Denis, M. On the Structural Design of the Midship Section. David W. Taylor Model Basin Report, C-555. Wash. D.C., 1954.

2. Rawat, Pramud. "The Design Synthesis of Primary Ship Structure Using Iterative Approach," Unpublished M.I.T. Memo, 1965.

3. Defense Industrial Supply Center. Fleet Oriented Stock List - Price and Management Data Section. Wash. D.C., 1966?

4. Boston Naval Shipyard Engineered Standard No. S 10 00 004: Structural Weld Aluminum Steel General. Boston, 1966.

5. U.S. Navy. Bureau of Ships. Contract Drawing, No. DD 931-S0101-601895-Rev. A., Destroyer (DD931) Midship Section. Wash., D.C., 1952. (Declassified by OPNAV Instruction 5500.40B, dated 1 October 1962.)

6. Evans, J. Harvey. "Optimization of Midshipsection Structure." Paper presented at the Computer-Aided Ship Design and Construction Symposium, Wash., D.C., August 30-31, 1966. (Mimeographed.)

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